

ANNOUNCEMENT 80TH ANNUAL MEETING  
FLORIDA ENTOMOLOGICAL SOCIETY

The 80th Annual Meeting of the Florida Entomological Society will be held August 4-7, 1997, at the Adam's Mark Hotel, Daytona Beach Resort, 100 North Atlantic Ave., Daytona Beach, FL 32118. Phone: (800) 444-2326; FAX: (904) 253-8841.

SUBMISSION OF PAPERS

The deadline for submission of papers for the 80th Annual Meeting of the Florida Entomological Society will be **Friday, May 9, 1997**. Time allotted for submitted oral papers will be eight minutes for presentation and two minutes for discussion. Confirmation of receipt of papers will be sent to the first author. There will be oral student paper sessions with awards as in previous years. A description of the format for judging the student papers is printed in the Newsletter. Students participating in the judged sessions must be members of the Florida Entomological Society and registered for the meeting.

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- \_\_\_\_\_ Oral Presentation
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**DEADLINE: May 9, 1996**

Author's Name \_\_\_\_\_

Title of Paper \_\_\_\_\_

\_\_\_\_\_

Affiliation and Address \_\_\_\_\_

of the First \_\_\_\_\_

(Presenting) Author \_\_\_\_\_

Abstract: *Must* be Provided. Do *not* use more than 75 words.

CITRUS RUST MITE (ACARI: ERIOPHYIDAE) COUNTS ON  
FRUIT AND THE NEGATIVE BINOMIAL DISTRIBUTION

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ABSTRACT

Count data for the number of citrus rust mites per cm<sup>2</sup> on fruit across a 4-ha (10-acre) area of orange trees followed the negative binomial probability distribution 79% of the time based on chi-square tests. A correlation of  $r = 0.993$  was found between observed counts and counts projected based on the distribution. A common  $k$  of 0.149 was computed but generally appeared more suitable for mean densities of 3.0 to 55.0 than 0.5 to 3.0 citrus rust mites per cm<sup>2</sup>. For mean densities of from 0.5 to 55 citrus rust mites per cm<sup>2</sup>, the parameter  $k$  of the negative binomial was related to the mean density ( $\bar{x}$ ):  $k = 0.081 + 0.1139 * (\log_{10} \bar{x})$ . Estimated  $k$ -values were used to draw expected count data profiles for several mean densities ranging from 1 to 40 citrus rust mites per cm<sup>2</sup>. Due to the skewness of the count data, the number of mites per cm<sup>2</sup> expected in most individual samples was always considerably smaller than the average density. Based on the negative binomial, mean rust mite densities could be estimated from the percentage of samples with at least one mite. Results of the study provide a means to predict the relative frequency histogram of densities associated with a mean density of citrus rust mites per cm<sup>2</sup> across an area of trees.

Key Words: citrus rust mite, *Phyllocoptruta oleivora*, sampling, negative binomial distribution

RESUMEN

Los datos del número de *Phyllocoptruta oleivora* por cm<sup>2</sup> en frutos de naranja en un área de 4 ha (10 acres) siguieron una distribución de probabilidad binomial negativa en el 79% de los casos, basada en pruebas de chi-cuadrada. Fue encontrada una correlación de  $r = 0.993$  entre los conteos observados y los proyectados sobre la base de la distribución. Una  $k$  común de 0.149 fue computada, aunque en general pareció ser más adecuada para densidades medias de 3.0 a 55.0 que para densidades de 0.5 a 3.0 ácaros por cm<sup>2</sup>. Para densidades promedio de 0.5 a 55 por cm<sup>2</sup>, el parámetro  $k$  de la binomial negativa estuvo relacionado con la densidad promedio ( $\bar{x}$ ):  $k = 0.081 + 0.1139 * (\log_{10} \bar{x})$ . Los valores estimados de  $k$  fueron usados para calcular los perfiles de los datos de conteo esperados para varias densidades medias en el rango de 1 a 40 ácaros por cm<sup>2</sup>. Debido a la desviación de los datos de los conteos, el número de ácaros por cm<sup>2</sup> esperado en la mayoría de las muestras individuales fue siempre considerablemente menor que la densidad promedio. Tomando como base la binomial negativa, las densidades medias de ácaros podrían ser estimadas a partir del porcentaje de muestras con al menos un ácaro. Los resultados del estudio proveen medios para predecir

el histograma de frecuencia relativa de densidades asociadas con una densidad promedio de *P. oleivora* por cm<sup>2</sup> en un área con árboles.

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Average densities of the citrus rust mite (CRM) [*Phyllocoptruta oleivora* (Ashmead)] per cm<sup>2</sup> on fruit across an area of orange trees can be estimated from counts of the number of mites present within a one-cm<sup>2</sup> surface area per fruit (Hall *et al.* 1994). The number of fruit and trees that must be sampled depends upon both the desired precision of estimates and the density of mites at which this precision is required.

If the probability distribution (e.g., see Gomez & Gomez 1984) associated with CRM count data is known, the frequency histogram of individual counts associated with a particular mean density can be projected. This would be useful for projecting damage by a CRM population and for establishing control levels. Histograms of CRM counts taken within individual trees usually followed the negative binomial probability distribution (Hall *et al.* 1991). No information was available on probability distributions describing CRM count data from fruit over an area of trees.

We had a considerable amount of CRM count data from fruit samples taken across 4-ha (10-acre) areas of 'Hamlin' and 'Valencia' orange trees in Florida (Hall *et al.* 1994). Previous analyses of the data indicated that the counts usually followed an aggregated distribution (Hall *et al.* 1994). Because aggregated dispersions often follow the negative binomial probability distribution (Southwood 1978), and because CRM count data from individual trees usually followed the negative binomial, we evaluated this distribution for projecting the frequency histograms of our count data.

#### MATERIALS AND METHODS

Count data were obtained on the number of CRM per cm<sup>2</sup> on fruit across 32 4-ha blocks of 'Hamlin' and 'Valencia' orange trees using a transect sampling plan (Hall *et al.* 1994). This plan consisted of 192 1-cm<sup>2</sup> samples per block - two samples per fruit, four fruit per tree (1 from each compass quadrant), 12 trees along one transect between the northeast and southwest corners of the block, and 12 trees along a second transect between the northwest and southeast corners of the block. All CRM except eggs within a 1-cm<sup>2</sup> sample were counted using a 10X magnifier fitted with a 1-cm<sup>2</sup> grid of 25 equal-sized subdivisions. In cases where >35 CRM per cm<sup>2</sup> were present, the number of mites was sometimes estimated by counting the number of mites in a diagonal row of five grid subdivisions and multiplying by 5. The block samples were taken during May through December within several different citrus growing areas in Florida. The only treatment applied to the blocks during the study was a summer spray of copper and oil. No samples were taken until at least 6 wk after this treatment.

The negative binomial probability distribution is characterized by two parameters, the mean ( $\bar{x}$ ) and a coefficient  $k$  (Johnson & Kotz 1969). The value of the  $k$  parameter defines the shape of the negative binomial distribution and serves as a general indicator of aggregation, with smaller values of  $k$  indicating increased aggregation (Southwood 1978). An iterative solution was used to manually estimate  $k$  for each block averaging at least 0.5 CRM per cm<sup>2</sup> (25 blocks):

$$N \cdot \log_e \left[ 1 + \frac{\bar{x}}{k} \right] = \sum \left[ \frac{Ax}{k+x} \right] \quad (1)$$

with  $N$  = total number of samples,  $\log_e$  = natural logs, and  $Ax$  = the sum of all frequencies of sampling units containing more than  $x$  individuals (Bliss & Fisher 1953, Southwood 1978).

The 25  $k$  estimates were then evaluated using regression procedures presented by Bliss & Owen (1958) and Bliss (1958) to determine if a single, *common*  $k$  ( $k_c$ ) existed. This involved regressing two statistics for each block,  $y' [= s^2 - \bar{x}]$  on  $x' [= \bar{x}^2 - (s^2/N)]$ , where  $\bar{x}$  was the mean,  $s^2$  the variance and  $N$  the number of individual counts per block. The regression was forced through the origin, and  $k_c$  was estimated from the inverse of the slope of the regression. The adequacy of this  $k_c$  estimate was evaluated using a regression analysis of  $1/k$  on  $\log_{10}(\bar{x})$ : a trend between these variables discredits the suitability of a single  $k_c$  (Bliss & Owen 1958, Southwood 1978).

One way to write negative binomial probabilities is:

$$p_x = \frac{(x+k-1)!}{x!(k-1)!} \cdot \left[ \frac{k}{k+\bar{x}} \right]^k \cdot \left[ \frac{\bar{x}}{k+\bar{x}} \right]^x \quad x = 0, 1, 2 \dots \quad (2)$$

where  $p_x$  is the probability of a sample having  $x$  mites (Williamson & Bretherton 1963). To determine the histogram of CRM counts expected in each block according to the negative binomial, we used observed mean densities and estimates of  $k$  in the following iterative probability formula:

$$p_{x+1} = \frac{k+x}{x+1} \cdot \left[ \frac{\bar{x}}{k+\bar{x}} \right] \cdot p_x \quad x = 0, 1, 2 \dots \quad (3)$$

with the probability of no mites ( $x=0$ ) being

$$p_{x=0} = \left[ \frac{k}{k+\bar{x}} \right]^k$$

where  $p_x$  = the probability of a sample containing  $x$  mites. Equation (3) was obtained by writing successive terms for  $p_0, p_1, p_2, \dots$  from equation (2) and noting the common multiplier. Using this iterative method avoids brute force calculation of the combinatorials which often cause computer overflow for large values of  $x$ . We programmed SAS (SAS Institute Inc. 1990) software to compute the successive probabilities. Chi-square tests ( $\alpha = 0.05$ ) according to guidelines presented by Gomez & Gomez (1984) and correlation analyses were used to test the fit of the observed CRM counts to those expected under the negative binomial based on estimated  $k$ -values.

#### RESULTS AND DISCUSSION

The mean density of CRM observed in the 25 blocks ranged from 0.5 to 112.5 per  $\text{cm}^2$ . A regression analysis indicated that the maximum density of CRM ( $\bar{y}$ ) observed in each block could be estimated from the mean density ( $\bar{x}$ ):  $y = 32.5 + 17.3^*x$ ;  $r^2 = 0.85$ ,  $F = 123.1$ ,  $PR > F = 0.0001$ ,  $d.f. = 23$ .

Individual estimates of the negative binomial  $k$  ranged from 0.0199 to 1.58 ( $\bar{k} = 0.2147$ ,  $s = 0.3025$ ) (Fig. 1). With respect to investigations into  $k_c$ , an initial plot of  $y'$  on  $x'$  indicated that one data point clearly deviated from the main trend of the regression (Fig. 2). This data point, which was associated with a mean density of 112.5 CRM per  $\text{cm}^2$  and a  $k$  value of 1.58, was excluded from further investigations into  $k_c$  but indicated that CRM aggregation may substantially decrease as population densities increase to as high as 100 or more CRM per  $\text{cm}^2$ .

Among the 24 sets of count data retained for  $k_c$  determination, mean densities ranged from 0.5 to 54.9 CRM per  $\text{cm}^2$  ( $\bar{x} = 12.96$  per  $\text{cm}^2$ ,  $s = 16.9$ ). The individual  $k$  estimates for the blocks varied from 0.0199 to 0.3580 ( $\bar{k} = 0.158$ ,  $s = 0.1052$ ). A  $k_c$  of 0.149 was calculated ( $F = 141.7$ ,  $\text{Pr} > F = 0.0001$ ,  $r^2 = 0.86$ ,  $\text{d.f.} = 24$ ) ( $r^2$  corrected for the mean = 0.83,  $\text{d.f.} = 23$ ) (Fig. 2). A statistically insignificant relationship ( $\alpha = 0.05$ ) was found between  $1/k$  and  $\bar{x}$  number CRM per  $\text{cm}^2$ , but a weak relationship ( $r^2 = 0.395$ ) was found between  $1/k$  and  $\log_{10}(\bar{x})$  number CRM per  $\text{cm}^2$  (Fig. 3), which indicated the  $k_c$  of 0.149 may not have been a suitable substitute for all of the individual  $k$ -values. A similar problem was reported with respect to determining a  $k_c$  associated with a set of wireworm counts (Bliss & Owen 1958). Variability in individual  $k$ -values associated with small mean CRM densities (*e.g.*, 0.5 to 3.0 CRM per  $\text{cm}^2$ ) was responsible for this trend; no significant trend was found between  $1/k$  and  $\log_{10}(\bar{x})$  number CRM per  $\text{cm}^2$  among mean densities of from 3 to 55 CRM per  $\text{cm}^2$  ( $N = 15$ ), and the same  $k_c$  (0.149) was calculated across these densities.

Because  $k_c$  tended to be a poor substitute for individual  $k$ -values at mean densities below around 3.0, as an alternative to  $k_c$  we conducted a regression analysis and determined an equation for estimating  $k$  across different mean densities ( $\bar{x}$ ):  $k = 0.081 +$

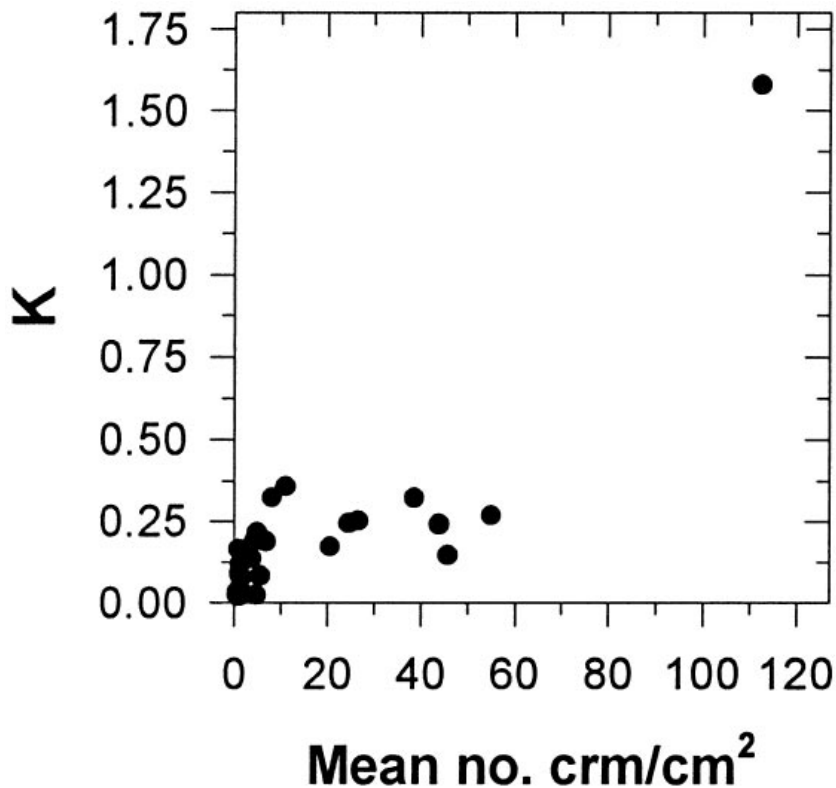


Fig. 1. Negative binomial  $k$ -values associated with observed mean densities of citrus rust mites (crm) per  $\text{cm}^2$  on fruit across 4-ha areas of orange trees.

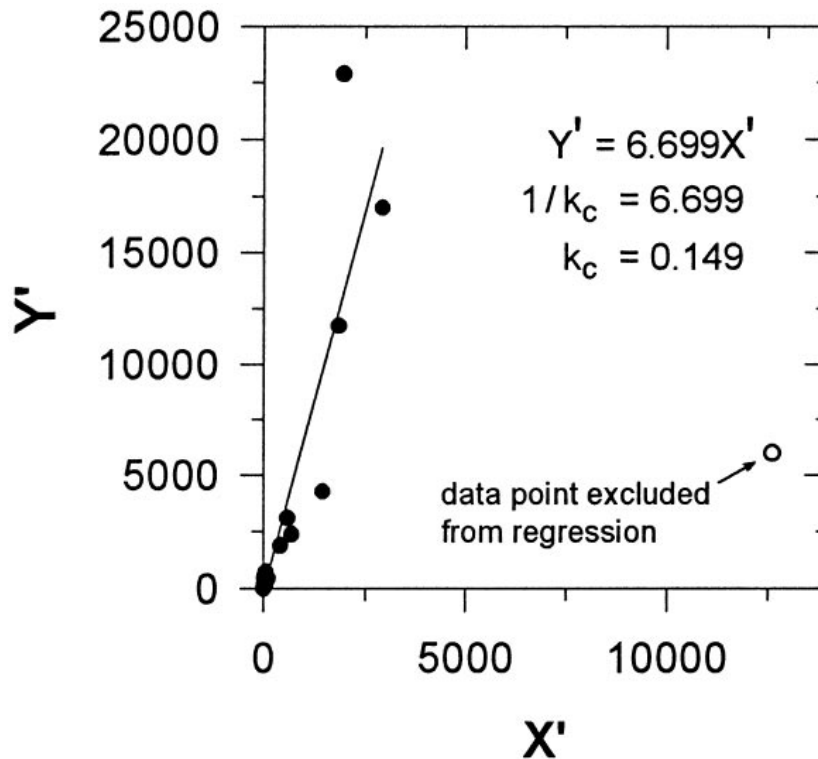


Fig. 2. Regression analysis used to calculate a single, common  $k$  ( $k_c$ ) for a negative binomial distribution describing the number of citrus rust mites per  $\text{cm}^2$  on fruit across 4-ha areas of orange trees. The open circle represents a data point excluded from the regression; this data point was associated with a mean of 112.5 mites/ $\text{cm}^2$  and a  $k$  of 1.58.

0.1139\*( $\log_{10} \bar{x}$ );  $F = 27.11$ ;  $\text{Pr} > F = 0.0001$ ;  $r^2 = .55$ ; d.f. = 23. A comparison of some histograms generated from individual, common and regressed  $k$ -values is presented in Fig. 4.

Chi-square tests indicated that CRM counts across a 4-ha area of trees followed the negative binomial distribution in 19 of 24 (79%) areas based on individual  $k$ -values and in 16 of 24 (67%) areas based on either  $k_c$  or regressed  $k$ -values. Among the observed count histograms that did not follow the negative binomial based on chi-square tests, these histograms visually resembled the distribution (e.g., Fig. 4). Over all 24 sets of CRM count data, the correlation between observed counts and counts projected using the negative binomial was 0.993 based on individual  $k$ -values, 0.976 based on regressed  $k$ -values, and 0.965 based on the  $k_c$  estimate. Among the 24 count sets, the lowest correlation between observed counts and counts expected under the negative binomial was 0.929, 0.921 and 0.872 based on individual  $k$ -values, regressed  $k$ -values and  $k_c$ , respectively.

Overall, counts of the number of CRM per  $\text{cm}^2$  on fruit across a 4-ha area of trees appeared to be at least reasonably described by the negative binomial distribution when mean densities were in the range of 0.5 to 55 per  $\text{cm}^2$ . The distribution in con-

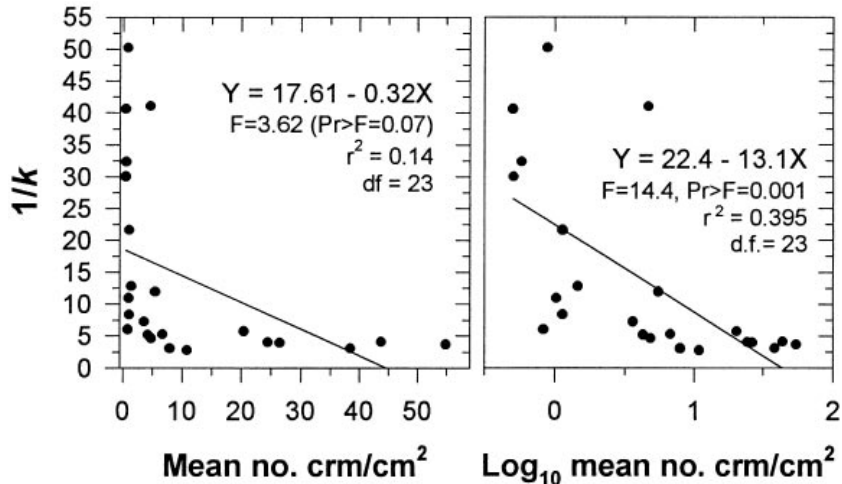


Fig. 3. Relationship between  $1/k$  and  $\bar{x}$  compared to  $1/k$  and  $\log_{10}\bar{x}$  number of citrus rust mites (crm) per  $\text{cm}^2$  on fruit across a 4-ha area of orange trees.

junction with the  $k$  parameter could therefore be used to project the frequency histogram of CRM densities at any mean density within this range, which in turn could be used in combination with models projecting how much surface damage to fruit a given density of CRM will cause (e.g., see Allen 1976, Yang *et al.* 1995) for an overall estimate of damage a CRM population will cause. The distribution could also be used to develop a sequential sampling plan (Southwood 1978), which might reduce the cost of sampling CRM. While histograms projected based on  $k_c$  were similar to those based on regressed  $k$  values, overall our analyses favored histograms based on the regressed estimates. As a word of caution,  $k$  values and the goodness-of-fit of the negative binomial distribution could be negatively influenced by extraneous factors that affect mite dispersion in a grove (e.g., chemical applications).

Expected profiles of CRM counts for a number of mean densities ranging from 1 to 40 mites per  $\text{cm}^2$  were projected based on the negative binomial using regression estimates of  $k$  in formula #3 (Fig. 5). Differences were relatively small between means of 1 to 40 mites per  $\text{cm}^2$  with respect to the projected probability of any individual count in the range of 5 to 15 mites per  $\text{cm}^2$ . Due to the skewness of CRM count data, the number of mites per  $\text{cm}^2$  expected in most individual samples was always considerably smaller than the average density. For example, at an average density of 5 CRM per  $\text{cm}^2$ , fewer than 5 mites per  $\text{cm}^2$  were expected to be present in around 80% of the individual samples across a 4-ha area. This information would be important to a citrus grower who might mistakenly assume that an average density based on scouting data reflects the midpoint of densities present. As the mean density increased, the probability increased that any particular large count would be observed. For example, the expected percentage of counts above 30 mites per  $\text{cm}^2$  increased from about 4% at a mean of 5 mites per  $\text{cm}^2$  up to about 18% at a mean of 20 mites per  $\text{cm}^2$ . The skewness of CRM count data supported contentions made by McCoy *et al.* (1976), namely that a control threshold should take into consideration the frequency histogram of mite counts.

Given that count data follow the negative binomial and  $k$  is known, expected mean densities can be estimated from the percentage of samples containing at least one an-



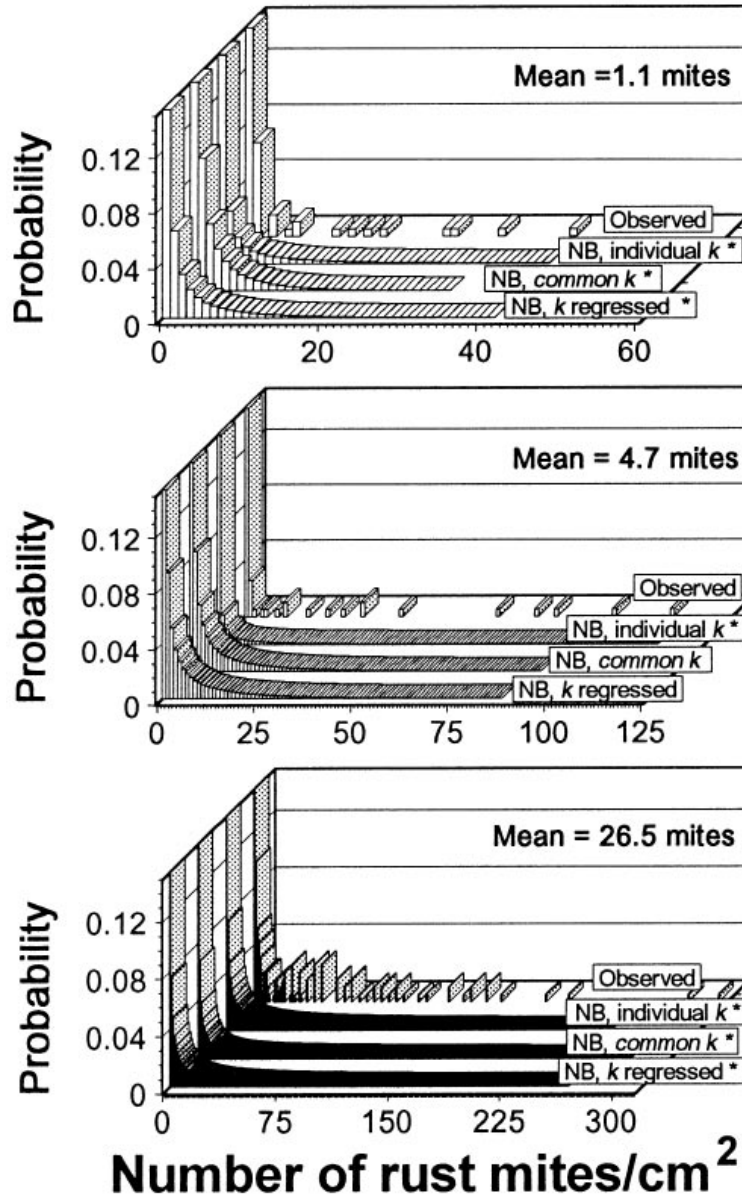


Fig. 4. Probability (proportion) of observed counts of citrus rust mites per cm<sup>2</sup> compared to counts projected from negative binomial (NB) distributions derived from individual, common and regressed  $k$ -values (largest observed counts shown, probabilities below 0.0001 or above 0.15 not shown). An asterisk (\*) indicates the observed histogram followed the projected histogram based on a chi-square test ( $\alpha = 0.05$ ).

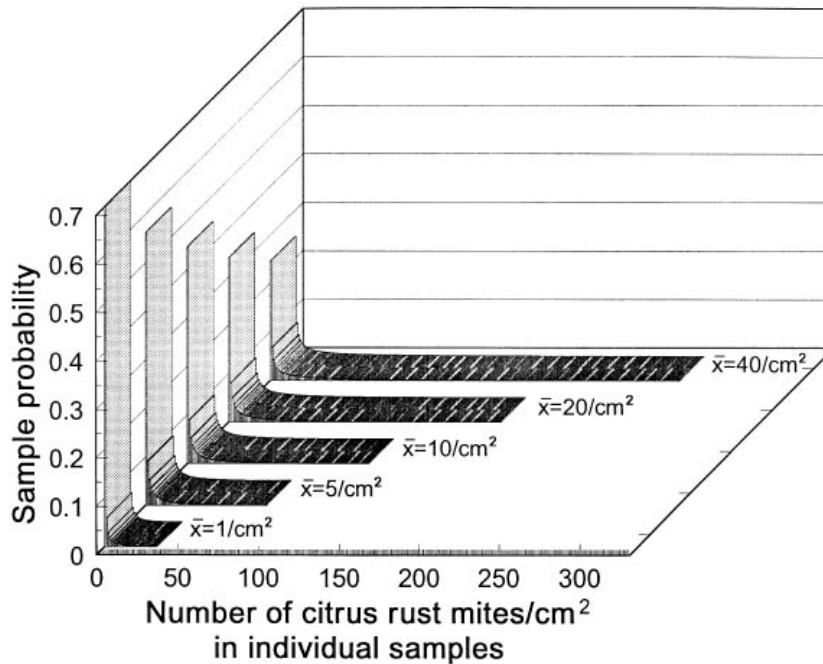


Fig. 5. Projected frequency distributions for citrus rust mite counts per  $\text{cm}^2$  on fruit across a 4-ha area of orange trees based on the negative binomial and regressed  $k$ -values, means of 1, 5, 10, 20 and 40 mites per  $\text{cm}^2$  (class probabilities below 0.00025 and above 0.7 not shown). The zero-class probability extended up to 0.81 at a mean of 1 mite per  $\text{cm}^2$ .

imal (see Southwood 1978). The relationship between mean CRM density and the percentage of infested samples based on the negative binomial is presented in Fig. 6. Similar relationships between percentages of infested samples and mean CRM densities have been observed without the use of a probability distribution (Knapp & Fasulo 1983, McCoy *et al.* 1976). The percentage of samples infested became increasingly poorer as an indicator of mean density as CRM densities increased. Benefits and precautions associated with using the percentage of infested samples as an indicator of mean CRM densities have been discussed (McCoy *et al.* 1976).

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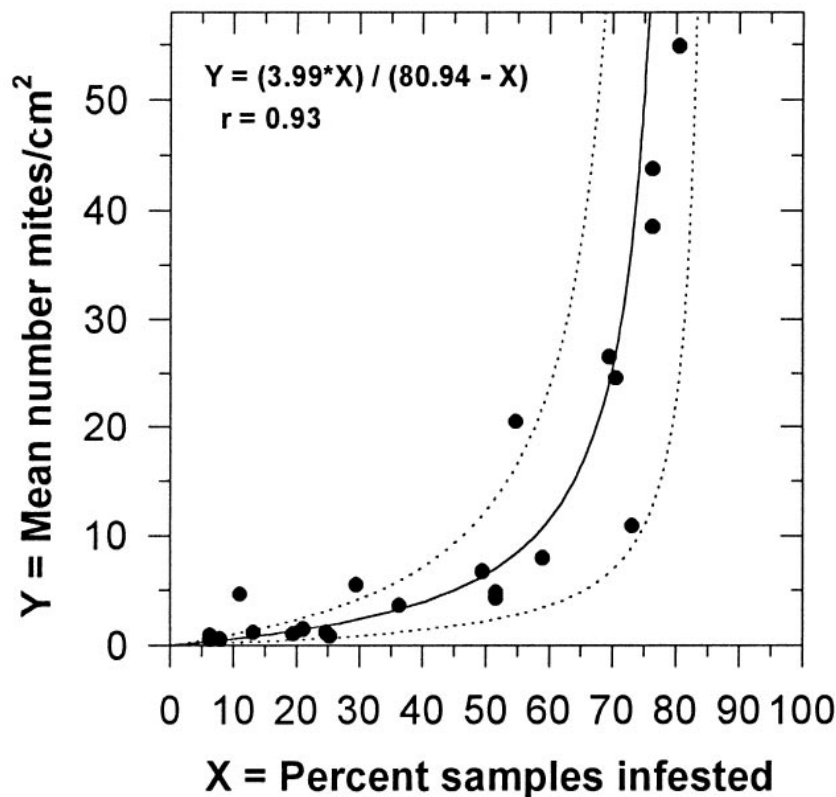


Fig. 6. Relationship between the mean density of citrus rust mites per  $\text{cm}^2$  on fruit across a 4-ha area of trees and the percentage of 1- $\text{cm}^2$  samples with at least one rust mite. Parameter estimates (standard error) associated with the hyperbola were 80.94 (1.166) and 3.994 (0.1905). A 95% confidence interval is given by the dotted lines. Percent samples infested ( $x$ ) can be estimated from the mean number of mites/ $\text{cm}^2$  ( $y$ ) by:  $x = (80.94 * y) / (3.99 + y)$ .

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EFFECT OF INSECTICIDES ON TWO PREDATORS OF THE  
COLORADO POTATO BEETLE (COLEOPTERA:  
CHRYSOMELIDAE)

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ABSTRACT

The effect of insecticides currently used in commercial eggplant fields to control the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) on two egg predators, *Coleomegilla maculata* DeGeer and *Chrysoperla carnea* (Stephens) was evaluated. Mortality from contact exposure to leaf residues, topical applications, and ingestion of contaminated eggmasses was compared for the following insecticides: esfenvalerate alone and in combination with piperonyl butoxide (PBO); oxamyl; PBO; and rotenone alone and in combination with PBO. Topical exposure and feeding studies were conducted using concentrations 1.00, 0.90, 0.80, 0.70, 0.60, 0.50, 0.40, 0.30, 0.20, and 0.10X the maximum labeled dose; leaf exposure studies were conducted using concentrations 1.00, 0.75, 0.50, and 0.25X the maximum labeled dose. Mortality of *C. maculata* adults and larvae from topical exposure was high after 48 h of exposure for all chemicals and doses. Mortality from topical exposure was low for *C. carnea* larvae in all cases when compared to PBO alone. Mortality from exposure to leaf residues was low in all cases for *C. maculata* adults but varied, depending on dose and chemical, for both *C. maculata* and *C. carnea* larvae. For all treatments, ingestion of treated eggs negatively affected the feeding and survival of *C. maculata* adults and larvae and *C. carnea* larvae. Esfenvalerate combined with PBO had the greatest effect on *C. maculata* adults; rotenone combined with PBO had the greatest effect on *C. maculata* larvae; esfenvalerate combined with PBO affected *C. carnea* larvae the most.

Key Words: *Coleomegilla maculata*, *Chrysoperla carnea*, insecticides, eggplant, IPM, *Leptinotarsa decemlineata*

## RESUMEN

Fue evaluado el efecto de los insecticidas comunmente usados en campos comerciales de berenjena para el control del escarabajo de Colorado, *Leptinotarsa decemlineata* (Say), sobre dos depredadores de huevos, *Coleomegilla maculata* DeGeer y *Chrysoperla carnea* (Stephens). Fue comparada la mortalidad por exposición a residuos en las hojas, aplicaciones tópicas, e ingestión de masas de huevos contaminadas con los siguientes insecticidas: esfenvalerate solo y en combinación con piperonyl butoxide (PBO); oxamyl; PBO; y rotenone solo y en combinación con PBO. Los ensayos de exposición tópica fueron efectuados utilizando concentraciones de 1.00, 0.90, 0.80X, 0.70, 0.60, 0.50, 0.40, 0.30, 0.20, y 0.10X de la dosis máxima recomendada para los productos. Los estudios de exposición de las hojas fueron conducidos usando concentraciones de 1.00, 0.75, 0.50, y 0.25X de la dosis máxima recomendada. La mortalidad de los adultos y larvas de *C. maculata* mediante exposición tópica fue alta luego de 48 horas de exposición a todos los productos y dosis. La mortalidad de las larvas de *C. carnea* mediante exposición tópica fue baja en todos los casos cuando se comparó con con el PBO solo. La mortalidad mediante exposición a residuos en las hojas fue baja en todos los casos para los adultos de *C. maculata* pero varió con la dosis y el producto en las larvas de *C. maculata* y *C. carnea*. En todos los tratamientos, la ingestión de huevos tratados afectó negativamente la alimentación y sobrevivencia de los adultos y larvas de *C. maculata* y de las larvas de *C. carnea*. El esfenvalerate combinado con PBO tuvo el mayor efecto en los adultos *C. maculata*, el rotenone combinado con PBO tuvo el mayor efecto en las larvas de *C. maculata*, el esfenvalerate combinado con PBO fue el producto que más afectó a las larvas de *C. carnea*.

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In New Jersey, the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is a key pest in eggplant and, if left uncontrolled, subsequent defoliation can completely destroy the crop (Cotty & Lashomb 1982). Colorado potato beetle populations have become resistant to most chemical insecticides resulting in difficulty in protecting the crop (Forgash 1985). During the late 1980s, a biological control intensive pest management program (BCIPM), using the egg parasitoid *Edovum puttleri* Grissell (Hymenoptera: Eulophidae), was implemented to reduce grower reliance on insecticides (Lashomb 1989). This program uses field scouting, weekly parasitoid releases, and insecticide applications pre- and post-release if either eggmass or larva/adult economic thresholds are reached.

A side benefit to this successful program has been increased populations of several indigenous natural enemies of Colorado potato beetle including *Coleomegilla maculata* DeGeer and *Chrysoperla carnea* (Stephens) (Lashomb unpublished) not found in non-BCIPM fields. Fields not utilizing biocontrol are repeatedly treated with various insecticides including esfenvalerate, oxamyl and rotenone (Hamilton 1995). The lack of natural enemies suggests that insecticide usage may be adversely affecting non-target species such as *C. maculata* and *C. carnea*. Several studies have documented the effect of various insecticides on *C. maculata* and *C. carnea*; however, these materials are not used in eggplant. This study evaluated the effect of insecticides commonly applied to eggplants for Colorado potato beetle control on *C. maculata* and *C. carnea*.

## MATERIALS AND METHODS

*C. maculata* DeGeer (larvae and adults) and *C. carnea* (Stephens) (larvae) were used in all studies. *C. maculata* adults and larvae were obtained from the USDA Ben-

eficial Insect Laboratory (Mission, TX); *C. carnea* from Rincon-Vitova Insectaries, Inc. (Ventura, CA). Before each study, all individuals were held in a Precision® growth chamber maintained at  $26 \pm 1^\circ\text{C}$ ,  $45 \pm 5\%$  RH and a photoperiod of 15:9 [L:D].

Three commonly used insecticides, esfenvalerate (Asana XL®, E. I. Dupont, Wilmington, DE), oxamyl (Vydate L®, E.I. Dupont, Wilmington, DE), and rotenone (Rotenox®, Fairfield American, Frenchtown, NJ) and 1 synergist, piperonyl butoxide (PBO) (Butoxide®, Fairfield American, Frenchtown, NJ) were tested. Combinations of esfenvalerate and PBO, and rotenone and PBO were also tested. The topical exposure and egg feeding studies were conducted using concentrations [g (AI) per liter] of approximately 1.0, 0.90, 0.80, 0.70, 0.60, 0.50, 0.40, 0.30 and 0.20X of the maximum labeled dose recommended for controlling Colorado potato beetle (esfenvalerate - 0.12, 0.11, 0.096, 0.08, 0.07, 0.06, 0.05, 0.036, and 0.02X respectively; oxamyl - 1.20, 1.08, 0.96, 0.84, 0.72, 0.60, 0.48, 0.36, and 0.24X, respectively; PBO - 2.39, 2.15, 1.91, 1.67, 1.43, 1.20, 0.96, 0.72, and 0.48X, respectively; rotenone - 7.66, 6.89, 6.13, 5.34, 4.60, 3.83, 3.06, 2.30, and 1.53X, respectively) and a water control. Leaf exposure studies were conducted using concentrations [g (AI) per liter] of approximately 1.0, 0.75, 0.50 and 0.25X of the maximum labeled dose recommended for controlling Colorado potato beetle (esfenvalerate - 0.12, 0.09, 0.06, and 0.03X, respectively; oxamyl - 1.20, 0.90, 0.60, and 0.30X, respectively; PBO - 2.39, 1.79, 1.20, and 0.60X, respectively; rotenone - 7.66, 5.75, 3.83, and 1.92X, respectively) and a water control.

#### Topical Exposure Tests

The effect of topically applied insecticides on *C. maculata* adults and larvae, and on *C. carnea* larvae was evaluated. For each material and dose, 100 *C. maculata* adults were treated with 10  $\mu\text{l}$  of insecticide using a Burkhardt® metered micro-syringe applicator. Treated individuals were then placed into vented 9-cm petri dishes (10 per dish) containing moistened filter paper and held for 48 h. Mortality was recorded at 24 and 48 h post exposure. All individuals were removed after 48 hours, recounted, and the mean percent mortality was determined. This procedure was repeated for both *C. maculata* and *C. carnea* larvae with the exception that treatments were made using 1  $\mu\text{l}$  of insecticide.

#### Leaf Exposure Tests

The effect of insecticide leaf residues on *C. maculata* adults and larvae, and *C. carnea* larvae was evaluated using treated leaf disks. For each material, dose and species, 10 eggplant leaves were excised and the petioles inserted into an Oasis® rootcube moistened with water and trimmed to 63.5  $\text{cm}^2$  leaf disks using a 9-cm plastic petri dish placed over the midrib. Each leaf disk was dipped into 100 ml of the respective concentration for each material, air dried, and placed into vented 9-cm petri dishes. Ten individuals were introduced into each petri dish and held for 48 hours. Mortality was recorded at 24 and 48 h post exposure. All individuals were removed after 48 hours, recounted, and the mean percent mortality was determined.

#### Feeding and Survival Tests

The effect of insecticides topically applied to *L. decemlineata* eggmasses on feeding and survival of *C. maculata* adults and larvae, and *C. carnea* larvae was determined. Eggmasses were obtained by rearing Colorado potato beetle larvae to adults and allowing them to lay eggs on caged potato plants maintained in the greenhouse under

25.0 ± 2.0°C temperature and a photoperiod of 12:12 (L:D). Eggmasses were collected from plants and trimmed to 10 eggs per mass. For each species, one hundred trimmed eggmasses per concentration per chemical were treated with 10 µl of material per eggmass using a Burkhardt® metered micro-syringe applicator, allowed to air dry, and transferred to sealed Solo® plastic condiment cups (59.1 ml) (1 eggmass per cup). A single individual was then placed into each cup. Each day following the initiation of the test, all eggmasses were removed from cups, examined for evidence of feeding, and replaced with freshly treated eggs. Daily monitoring continued until either pupation or mortality occurred. The mean number of eggs fed upon and the survival rate of individuals was determined.

#### Statistical Analysis

Topical and leaf exposure percent mortality data were corrected using Abbott's (1925) and analyzed using probit analysis (Robertson & Preisler 1992, SAS 1987); feeding and survival data were transformed to SQRT(X + 1) (Snedecor and Cochran 1978) and analyzed using linear regression (SAS 1987).

## RESULTS AND DISCUSSION

#### Topical Exposure Tests

Topical exposure of *C. maculata* adults and larvae and *C. carnea* larvae to all materials tested resulted in mortality in all cases (Table 1). Mortality levels were consistently higher at 48 h post-exposure than at 24 h post-exposure. *C. maculata* adults were most sensitive to topical applications of esfenvalerate in combination with PBO after both 24 h and 48 h when compared to PBO alone (Table 2). Exposure to rotenone alone resulted in the lowest toxicity ratios observed. Overall, toxicity ratios for esfenvalerate alone and in combination with PBO for *C. maculata* larvae were higher than those observed for adults but lower for all other materials. Similar levels of mortality have been reported when *C. maculata* was topically exposed to cypermethrin, carbaryl, fenvalerate, malathion and permethrin (Coats et al. 1979, Lecrone & Smilowitz 1980, Roger et al. 1994). *C. carnea* larvae were least affected by topical applications when compared to PBO, thus supporting evidence that *C. carnea* is tolerant of certain pyrethroid and carbamate insecticides (Shour & Crowder 1980, Ihaaya & Casida 1981, Grafton-Cardell & Hoy 1985, 1986, Pree et al. 1989). Toxicity ratios at 48 h post-exposure were highest for esfenvalerate in combination with PBO, followed by oxamyl.

#### Leaf Exposure Tests

Exposure to foliar residues of the insecticides also resulted in high levels of mortality (Table 3). For each insecticide, mortality was highest at 48 h post-exposure. *C. maculata* adults, however, showed no response to low levels (0.25) of esfenvalerate alone, rotenone alone or in combination with PBO, or oxamyl. Exposure to leaves treated with esfenvalerate in combination with PBO resulted in the highest toxicity ratios observed for each species, followed by esfenvalerate alone and oxamyl (Table 2). *C. maculata* adults were least affected by exposure to the insecticides tested when compared to larvae. These findings contradict the work by Plapp & Bull (1978) that showed *C. carnea* to be less susceptible to contact residues of pyrethroid insecticides



TABLE 1. RESPONSE OF COLEOMEGILLA MACULATA AND CHRYSOPERLA CARNEA TO TOPICAL EXPOSURE TO SELECTED INSECTICIDES.

Insecticide	Mortality after 24 h			Mortality after 48 h		
	b ± SE <sup>1</sup>	LD <sub>50</sub> <sup>a</sup> g/liter (95% FL)	LD <sub>90</sub> <sup>a</sup> g/liter (95% FL)	b ± SE <sup>1</sup>	LD <sub>50</sub> <sup>a</sup> g/liter (95% FL)	LD <sub>90</sub> <sup>a</sup> g/liter (95% FL)
<b>Coleomegilla maculata adults</b>						
Esfenvalerate	0.86 ± 0.32	0.07 (0.04 - 0.29)	2.18 (1.41 - 2.31)	1.03 ± 0.37	0.01 (0.005 - 0.03)	0.19 (0.10 - 0.49)
Esfenvalerate & PBO	2.06 ± 0.55	0.02 (0.001 - 0.03)	0.07 (0.05 - 0.15)	3.86 ± 0.75	0.01 (0.007 - 0.02)	0.03 (0.02 - 0.04)
Rotenone	3.10 ± 0.35	6.07 (5.41 - 7.07)	15.72 (11.98 - 24.84)	2.42 ± 0.28	4.14 (3.62 - 4.73)	14.02 (10.57 - 22.56)
Rotenone & PBO	1.96 ± 0.41	0.97 (0.28 - 1.53)	4.34 (3.38 - 6.54)	1.22 ± 0.30	0.009 (0.0003 - 0.06)	2.12 (1.20 - 2.79)
Oxamyl	2.54 ± 0.22	0.36 (0.31 - 0.40)	1.15 (1.01 - 1.35)	3.02 ± 0.30	0.20 (0.16 - 0.23)	0.53 (0.48 - 0.59)
PBO	6.15 ± 1.16	3.38 (2.92 - 4.59)	5.43 (4.16 - 9.78)	1.73 ± 0.40	6.26 (3.64 - 7.15)	34.43 (11.15 - 57.71)
<b>Coleomegilla maculata larvae</b>						
Esfenvalerate	0.99 ± 0.23	0.003 (0.002 - 0.007)	0.06 (0.04 - 0.08)	— <sup>2</sup>	—	—
Esfenvalerate & PBO	1.91 ± 0.66	0.003 (0.0007 - 0.01)	0.02 (0.004 - 0.03)	— <sup>2</sup>	—	—
Rotenone	1.01 ± 0.21	12.20 (8.64 - 25.76)	229.35 (72.43 - 386.27)	1.22 ± 0.20	2.41 (1.79 - 2.91)	26.94 (16.75 - 65.71)
Rotenone & PBO	33.36 ± 0.13	1.40 (1.90 - 0.90)	1.53 (1.28 - 1.78)	31.32 ± 0.17	1.36 (0.95 - 1.77)	1.48 (1.15 - 1.63)
Oxamyl	4.22 ± 0.92	0.13 (0.07 - 0.17)	0.26 (0.21 - 0.30)	33.85 ± 0.13	0.22 (0.19 - 0.25)	0.24 (0.18 - 0.26)
PBO	2.09 ± 0.24	0.36 (0.25 - 0.45)	1.473 (1.30 - 1.73)	2.52 ± 0.61	0.20 (0.03 - 0.35)	0.54 (0.38 - 0.84)
<b>Chrysoperla carnea larvae</b>						
Esfenvalerate	2.01 ± 0.24	0.15 (0.13 - 0.19)	0.65 (0.42 - 1.29)	0.90 ± 0.19	0.14 (0.10 - 0.25)	3.71 (1.13 - 6.23)
Esfenvalerate & PBO	2.48 ± 0.26	0.11 (0.10 - 0.14)	0.38 (0.29 - 0.59)	1.45 ± 0.26	0.11 (0.09 - 0.18)	0.87 (0.40 - 1.34)

<sup>1</sup>n = 100<sup>2</sup>Analysis not conducted due to 100% mortality at all doses.

TABLE 1. (CONTINUED) RESPONSE OF COLEOMEGLILLA MACULATA AND CHRYSOPERLA CARNEA TO TOPICAL EXPOSURE TO SELECTED INSECTICIDES.

Insecticide	Mortality after 24 h			Mortality after 48 h		
	b ± SE <sup>1</sup>	LD <sub>50</sub> <sup>a</sup> g/liter (95% FL)	LD <sub>90</sub> <sup>a</sup> g/liter (95% FL)	b ± SE <sup>1</sup>	LD <sub>50</sub> <sup>a</sup> g/liter (95% FL)	LD <sub>90</sub> <sup>a</sup> g/liter (95% FL)
Rotenone	6.25 ± 0.59	7.46 (7.07 - 7.99)	11.96 (10.65 - 14.12)	4.06 ± 0.88	7.88 (6.50 - 12.49)	16.30 (10.94 - 27.24)
Rotenone & PBO	3.12 ± 0.45	13.03 (10.61 - 18.60)	33.55 (22.34 - 69.17)	1.70 ± 0.24	12.49 (9.77 - 18.90)	70.88 (41.15 - 103.13)
Oxamyl	0.92 ± 0.20	0.15 (0.05 - 0.24)	3.72 (2.10 - 4.33)	0.98 ± 0.21	0.10 (0.03 - 0.18)	2.06 (1.37 - 5.28)
PBO	1.86 ± 0.22	2.16 (1.90 - 2.59)	10.53 (7.11 - 19.62)	1.27 ± 0.20	2.03 (1.71 - 2.65)	20.90 (10.68 - 31.11)

<sup>1</sup>n = 100.<sup>2</sup>Analysis not conducted due to 100% mortality at all doses.

TABLE 2. TOXICITY RATIOS BASED ON TOPICAL AND FOLIAR RESIDUE EXPOSURE TO SELECTED INSECTICIDES FOR COLEOMEGILLA MACULATA AND CHRYSOPERLA CARNEA.

Insecticide	Toxicity Ratio <sup>1</sup> (Topical)						Toxicity Ratio <sup>1</sup> (Leaf Residues)					
	24 h Post-Exposure		48 h Post-Exposure		24 h Post-Exposure		48 h Post-Exposure		24 h Post-Exposure		48 h Post-Exposure	
	LD <sub>50</sub>	LD <sub>90</sub>	LD <sub>50</sub>	LD <sub>90</sub>	LD <sub>50</sub>	LD <sub>90</sub>	LD <sub>50</sub>	LD <sub>90</sub>	LD <sub>50</sub>	LD <sub>90</sub>	LD <sub>50</sub>	LD <sub>90</sub>
Coleomegilla maculata adults												
Esfenvalerate	48.29	2.49	626.00	181.21	16.95	31.27	14.61	38.55				
Esfenvalerate & PBO	169.00	77.57	626.00	1,147.67	21.87	2.77	37.57	17.26				
Rotenone	0.56	0.35	1.51	2.46	0.39	1.14	0.27	0.74				
Rotenone & PBO	3.48	1.25	695.56	16.24	0.66	1.78	0.36	1.05				
Oxamyl	9.39	4.72	31.30	64.96	3.66	10.49	2.12	1.00				
PBO	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
Coleomegilla maculata larvae												
Esfenvalerate	120.00	24.50	—	—	26.50	38.33	28.00	21.00				
Esfenvalerate & PBO	120.00	73.50	—	—	53.00	11.50	—	—				
Rotenone	0.03	0.01	0.08	0.02	0.03	0.01	0.14	0.04				
Rotenone & PBO	0.26	0.96	0.15	0.43	0.14	0.08	0.23	0.08				
Oxamyl	2.77	5.65	0.91	2.67	1.71	0.70	5.60	0.85				
PBO	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
Chrysoperla carnea larvae												
Esfenvalerate	14.40	16.20	14.50	5.63	50.08	1.40	176.67	20.75				

<sup>1</sup>Toxicity relative to PBO = LD<sub>PBO</sub>/LD<sub>Insecticide</sub> = Toxicity Ratio.

TABLE 2. (CONTINUED) TOXICITY RATIOS BASED ON TOPICAL AND FOLIAR RESIDUE EXPOSURE TO SELECTED INSECTICIDES FOR COLEOMEGLILLA MACULATA AND CHRYSOPERLA CARNEA.

Insecticide	Toxicity Ratio <sup>1</sup> (Topical)						Toxicity Ratio <sup>1</sup> (Leaf Residues)					
	24 h Post-Exposure		48 h Post-Exposure		24 h Post-Exposure		48 h Post-Exposure		24 h Post-Exposure		48 h Post-Exposure	
	LD <sub>50</sub>	LD <sub>90</sub>	LD <sub>50</sub>	LD <sub>90</sub>	LD <sub>50</sub>	LD <sub>90</sub>	LD <sub>50</sub>	LD <sub>90</sub>	LD <sub>50</sub>	LD <sub>90</sub>	LD <sub>50</sub>	LD <sub>90</sub>
Esfenvalerate & PBO	19.64	27.71	18.45	24.02	651.00	1,530.00	1,855.00	671.88				
Rotenone	0.29	0.88	0.26	1.28	1.54	0.91	11.28	3.23				
Rotenone & PBO	0.17	0.31	0.16	0.29	2.26	7.20	8.10	2.85				
Oxamyl	14.40	2.83	20.30	10.15	15.88	28.75	148.40	7.25				
PBO	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00				

<sup>1</sup>Toxicity relative to PBO = LD<sub>50</sub>/LD<sub>insecticide</sub> = Toxicity Ratio.

TABLE 3. RESPONSE OF COLEOMEGILLA MACULATA AND CHRYSOPERLA CARNEA EXPOSED TO FOLIAR RESIDUES OF SELECTED INSECTICIDES.

Insecticide	Mortality after 24 h			Mortality after 48 h		
	b ± SE <sup>1</sup>	LC <sub>50</sub> , g/liter (95% FL)	LC <sub>90</sub> , g/liter (95% FL)	b ± SE <sup>1</sup>	LC <sub>50</sub> , g/liter (95% FL)	LC <sub>90</sub> , g/liter (95% FL)
<b>Coleomegilla maculata adults</b>						
Esfenvalerate	0.88 ± 0.26	0.40 (0.22 - 0.62)	1.71 (0.57 - 2.28)	1.30 ± 0.24	0.18 (0.14 - 0.27)	0.47 (0.30 - 0.57)
Esfenvalerate & PBO	0.31 ± 0.13	0.31 (0.15 - 0.47)	19.32 (1.52 - 37.12)	0.47 ± 0.12	0.07 (0.05 - 0.10)	1.05 (0.81 - 1.28)
Rotenone	1.30 ± 0.36	17.56 (11.76 - 23.36)	47.10 (22.46 - 69.56)	1.38 ± 0.39	9.64 (8.88 - 10.40)	24.41 (23.65 - 25.17)
Rotenone & PBO	1.20 ± 0.37	10.33 (9.60 - 11.06)	30.06 (29.33 - 30.79)	1.49 ± 0.39	7.28 (6.52 - 8.04)	17.24 (16.48 - 18.00)
Oxamyl	1.26 ± 0.37	1.85 (1.50 - 2.58)	5.10 (4.37 - 5.83)	1.45 ± 0.34	1.24 (0.57 - 1.91)	3.01 (2.34 - 3.68)
PBO	0.62 ± 0.16	6.78 (3.93 - 9.63)	53.48 (15.74 - 91.58)	0.66 ± 0.13	2.63 (2.05 - 4.23)	18.12 (8.61 - 27.72)
<b>Coleomegilla maculata larvae</b>						
Esfenvalerate	9.30 ± 0.02	0.02 (-0.02 - 0.06)	0.03 (-0.01 - 0.07)	9.03 ± 0.20	0.02 (-0.26 - 0.32)	0.03 (-0.36 - 0.42)
Esfenvalerate & PBO	0.59 ± 0.19	0.01 (-0.37 - 0.37)	0.10 (-0.28 - 0.48)	— <sup>2</sup>	—	—
Rotenone	0.48 ± 0.14	15.28 (9.37 - 21.29)	218.90 (53.99 - 383.81)	0.85 ± 0.28	3.93 (3.38 - 4.48)	17.67 (17.01 - 18.25)
Rotenone & PBO	0.95 ± 0.13	3.75 (3.21 - 4.29)	14.41 (10.84 - 23.11)	1.05 ± 0.13	2.39 (1.92 - 2.79)	8.12 (6.71 - 10.88)
Oxamyl	0.77 ± 0.28	0.31 (-0.24 - 0.55)	1.65 (1.10 - 2.20)	0.64 ± 0.16	0.10 (0.02 - 0.18)	0.74 (0.57 - 1.11)
PBO	1.66 ± 0.42	0.53 (-0.29 - 1.35)	1.15 (0.33 - 1.97)	9.03 ± 0.20	0.56 (0.17 - 1.29)	0.63 (0.24 - 1.02)
<b>Chrysoperla carnea larvae</b>						
Esfenvalerate	0.21 ± 0.13	0.39 (0.30 - 0.48)	153.37 (129.24 - 177.5)	0.90 ± 0.12	0.21 (0.18 - 0.24)	2.59 (2.25 - 2.84)
Esfenvalerate & PBO	0.96 ± 0.13	0.03 (0.02 - 0.04)	0.14 (0.11 - 0.19)	1.04 ± 0.35	0.02 (0.01 - 0.03)	0.08 (0.05 - 0.11)

<sup>1</sup>n = 100.<sup>2</sup>Analysis not conducted due to 100% mortality at all doses.

TABLE 3. (CONTINUED) RESPONSE OF COLEOMEGLILLA MACULATA AND CHRYSOPERLA CARNEA EXPOSED TO FOLIAR RESIDUES OF SELECTED INSECTICIDES.

Insecticide	Mortality after 24 h			Mortality after 48 h		
	b ± SE <sup>1</sup>	LC <sub>50</sub> , g/liter (95% FL)	LC <sub>90</sub> , g/liter (95% FL)	b ± SE <sup>1</sup>	LC <sub>50</sub> , g/liter (95% FL)	LC <sub>90</sub> , g/liter (95% FL)
Rotenone	0.44 ± 0.13	12.68 (8.05 - 17.31)	236.23 (53.92 - 418.54)	0.79 ± 0.13	3.29 (2.66 - 3.87)	16.64 (11.62 - 32.21)
Rotenone & PBO	1.04 ± 0.31	8.65 (7.61 - 9.64)	29.74 (25.44 - 34.04)	0.91 ± 0.13	4.58 (3.97 - 5.33)	18.84 (13.33 - 34.32)
Oxamyl	0.71 ± 0.13	1.23 (0.99 - 1.81)	7.45 (3.88 - 9.98)	0.38 ± 0.12	0.25 (0.04 - 0.39)	7.41 (2.76 - 12.06)
PBO	0.53 ± 0.20	19.53 (6.51 - 32.55)	214.20 (26.46 - 401.94)	0.26 ± 0.14	37.10 (34.15 - 40.50)	53.75 (48.86 - 58.64)

<sup>1</sup>n = 100.<sup>2</sup>Analysis not conducted due to 100% mortality at all doses.

TABLE 4. SURVIVAL OF COLEOMEGILLA MACULATA AND CHRYSOPERLA CARNEA FED ON EGGS TREATED WITH SELECTED INSECTICIDES.

Insecticide	n	Number of Eggs Eaten per Day			Number of Days Survived		
		a ± 95% CL	b ± 95% CL	r <sup>2</sup>	a ± 95% CL	b ± 95% CL	r <sup>2</sup>
<b>Coleomegilla maculata adults</b>							
Esfenvalerate	100	1.30 ± 0.21	-1.40 ± 0.35	0.67*	4.83 ± 0.40	-4.28 ± 0.65	0.84*
Esfenvalerate & PBO	100	1.98 ± 0.50	-2.62 ± 0.80	0.57*	3.14 ± 0.40	-3.57 ± 0.64	0.79*
Rotenone	100	2.59 ± 0.18	-2.17 ± 0.29	0.88*	3.18 ± 0.36	-2.98 ± 0.58	0.77*
Rotenone & PBO	100	2.63 ± 0.33	-2.61 ± 0.54	0.75*	3.97 ± 0.41	-3.26 ± 0.66	0.75*
Oxamyl	100	2.11 ± 0.30	-2.19 ± 0.49	0.71*	5.05 ± 0.45	-4.90 ± 0.73	0.85*
PBO	100	2.25 ± 0.39	-2.84 ± 0.63	0.72*	4.16 ± 0.48	-4.79 ± 0.77	0.83*
<b>Coleomegilla maculata larvae</b>							
Esfenvalerate	100	1.82 ± 0.25	-1.40 ± 0.41	0.60*	2.94 ± 0.12	-0.53 ± 0.20	0.47*
Esfenvalerate & PBO	100	1.06 ± 0.36	-0.98 ± 0.59	0.26	3.29 ± 0.22	-1.74 ± 0.36	0.74*
Rotenone	100	4.15 ± 0.46	-1.53 ± 0.75	0.34	5.85 ± 0.17	-1.62 ± 0.27	0.81*
Rotenone & PBO	100	2.76 ± 0.26	-2.15 ± 0.42	0.77*	4.42 ± 0.08	-0.40 ± 0.13	0.55*
Oxamyl	100	3.36 ± 0.15	-1.94 ± 0.24	0.89*	4.33 ± 0.12	-1.36 ± 0.19	0.87*
PBO	100	2.69 ± 0.18	-1.31 ± 0.29	0.71*	5.37 ± 0.10	-1.16 ± 0.16	0.87*
<b>Chrysoperla carnea larvae</b>							
Esfenvalerate	100	4.50 ± 0.12	-1.32 ± 0.19	0.86*	6.29 ± 0.06	-0.25 ± 0.09	0.48*
Esfenvalerate & PBO	100	2.63 ± 0.13	-1.69 ± 0.21	0.89*	5.76 ± 0.14	-1.15 ± 0.23	0.75*
Rotenone	100	3.64 ± 0.05	-0.70 ± 0.05	0.90*	6.58 ± 0.07	-0.72 ± 0.11	0.85*

\*Significant at P ≤ 0.05.

TABLE 4. (CONTINUED) SURVIVAL OF COLEOMEGILLA MACULATA AND CHRYSOPERLA CARNEA FED ON EGGS TREATED WITH SELECTED INSECTICIDES.

Insecticide	Number of Eggs Eaten per Day				Number of Days Survived			
	n	a ± 95% CL	b ± 95% CL	r <sup>2</sup>	a ± 95% CL	b ± 95% CL	r <sup>2</sup>	
Rotenone & PBO	100	3.67 ± 0.09	-1.63 ± 0.14	0.94*	6.78 ± 0.08	-0.66 ± 0.14	0.74*	
Oxamyl	100	1.81 ± 0.09	-0.64 ± 0.14	0.72*	6.46 ± 0.08	-0.82 ± 0.13	0.84*	
PBO	100	4.81 ± 0.17	-1.43 ± 0.28	0.77*	6.98 ± 0.06	-0.50 ± 0.10	0.75*	

\*Significant at P ≤ 0.05.



when compared to various carbamate and organophosphate materials. The data also suggest that field applications of rotenone could have a detrimental effect on the larval populations of both predators.

#### Feeding and Survival Tests

All insecticide treatments negatively affected the feeding and survival of *C. maculata* and *C. carnea* (Table 4). Significant linear relationships ( $P \leq 0.05$ ) between dose and feeding were found for all insecticides and species tested with the exception of *C. maculata* larvae exposed to eggs treated with rotenone ( $r^2 = 0.34$ ) and esfenvalerate combined with PBO ( $r^2 = 0.26$ ). Esfenvalerate combined with PBO and PBO alone had the greatest effect on feeding by *C. maculata* adults ( $b = -2.62$  and  $-2.84$ , respectively), whereas rotenone combined with PBO had the greatest effect on *C. maculata* larvae ( $b = -2.15$ ), followed by oxamyl alone ( $b = -1.93$ ). Feeding by *C. carnea* larvae was most affected by esfenvalerate in combination with PBO and rotenone in combination with PBO ( $b = -1.69$  and  $-1.63$ , respectively). Overall, survival of larvae for both species was most affected by esfenvalerate combined with PBO. *C. maculata* adult survival was most affected by oxamyl ( $b = -4.90$ ). PBO alone, however, had little impact on the survival of *C. maculata* and *C. carnea* larvae but greatly reduced the survival of *C. maculata* adults ( $b = -4.79$ ). Egg mortality, as the result of insecticide treatments, may in part explain the decreased feeding levels and subsequent reduced survival observed. Insecticide repellency might also account for the drop in egg consumption. Finally, mortality of individuals from ingestion of surface residues could be responsible for reduced feeding. Adverse effects from the ingestion of treated food items have been reported for other insecticides. Singh & Varma (1986) found reductions in *C. carnea* survival from ingestion of *Corcyra cephalonica* Stainton eggs treated with several insecticides including, endosulfan, carbaryl, and cypermethrin. Giroux et al. (1994) demonstrated that ingestion of Colorado potato beetle eggs by *C. maculata* was reduced when eggs were treated with *Bacillus thuringiensis* var. *san diego*. Reduced survival due to ingestion of treated food material has also been reported for other coccinellids such as *Hippodamia convergens* Guérin-Méneville (Hurej & Dutcher 1994).

Our results show that *C. maculata* adults and larvae, and *C. carnea* larvae are susceptible to chemical insecticides commonly used to control Colorado potato beetle. This finding is important in terms of the design of a pest management program. It suggests that changing the types of insecticides applied may allow predator survival in fields thereby helping to reduce pest populations.

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A NEW *ENCARSIA* (HYMENOPTERA: APHELINIDAE) SPECIES  
REARED FROM THE *BEMISIA TABACI* COMPLEX  
(HOMOPTERA: ALEYRODIDAE)

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## ABSTRACT

*Encarsia polaszeki* Evans n. sp., reared from the *Bemisia tabaci* complex from Brazil, is described and illustrated.

Key Words: Sweetpotato whitefly, cotton whitefly, silverleaf whitefly, *Bemisia*, *Encarsia*, biological control

## RESUMEN

Se describe e ilustra *Encarsia polaszeki* Evans, criada del complejo de *Bemisia tabaci* de Brasil.

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The sweetpotato whitefly (SPWF), *Bemisia tabaci* (Gennadius), was described from tobacco in Greece in 1889 and was first reported in the New World (in Florida) by Quaintance in 1900. *B. tabaci* is widely distributed throughout most tropical and subtropical areas of the world. Increasing evidence suggests that there may be several closely related species and/or biotypes (or strains or races) of *B. tabaci* occurring in various parts of the world. The *B. tabaci* species complex is composed of three closely related or sibling species, namely, *B. tabaci*, *B. argentifolii* Perring and Bellows and *B. poinsettiae* Hempel, and their biotypes. Perring et al. (1993) estimated the damage caused by the silverleaf whitefly (SLWF), *B. argentifolia*, to U.S. agriculture at over a half a billion dollars.

*Encarsia* (Hymenoptera: Aphelinidae) species are among the most common and effective parasitoids of whiteflies and have been used successfully in biological control programs aimed at several different pest species. The greenhouse whitefly, (*Trialeurodes vaporariorum* (Westwood)), citrus blackfly (*Aleurocanthus woglumi* Ashby) and citrus whitefly (*Dialeurodes citri* (Ashmead)), have been brought under biological control in most areas of the world primarily by *Encarsia formosa* Gahan, *E. opulenta* (Silvestri) and *E. lahorensis* (Howard), respectively.

The search for natural enemies of the SPWF has been focused in the Orient and Middle East region, which was believed to be the native home of this pest (Mound 1963); (Lopez-Avila 1986). Gill (1992) provided evidence indicating that the SPWF (or SLWF) may have originated in the New World and suggested that the search for natural enemies of the SPWF species be focused on the Neotropics. *Encarsia polaszeki* was reared from the *B. tabaci* complex in abundant numbers at the two sites where it was collected and may be an effective natural enemy of the SPWF or its relatives in other areas of the world.

*Encarsia polaszeki* Evans, sp. nov. (Figs. 1-7)

#### Female

Length: Range = 0.45-0.55 mm, mean = 0.53 mm (based on 10 specimens)

Coloration: (Fig. 1) Body yellowish with head, pronotum, central portion of mesoscutum, axillae apices, metanotum, base of metasomal tergite I, dorsolateral margins of tergites I-V, and transverse band on tergite VI, dark brown; tergite VII dusky; eyes red; legs and antennae pale with F6 slightly darker than other segments; wings hyaline.

**Structure:** **Head** - postocellar bars prominent; mandibles tridentate; antenna (Fig. 4) comprised of radicle (R), scape (S), pedicel (P), 3 funicular segments (F1-3) and 3 club segments (F4-6) each having the following length/width ratios: 2.5, 4.6, 1.3, 1.6, 1.8, 2.0, 2.1, 2.0 and 2.5; relative lengths of segments R-F6 to length of F1: 1.1, 3.3, 1.4, 1.0, 1.3, 1.4, 1.5, 1.4 and 1.8; flagellum with the following number of linear sensilla: F1:0, F2:1, F3:2, F4:2, F5:3, F6:3, basiconic setae present on F2-F6. **Mesosoma** - mesoscutum 1.3 times as wide as long with broad hexagonal sculpturing and 2 pairs of slender setae; each parapsis with 2 setae; each axilla with 1 short seta, scutellum with 2 pairs of setae, Sc1 not reaching base of Sc2, distance between placoid sensillae 2.5-3.0 times the diameter of 1 sensillum; endophragma reaching base of metasomal tergite II; tibial spur of middle leg (Fig. 6) 0.7 times as long as corresponding basitarsus; tarsal formula 5-5-5; fore wing (Fig. 3) almond-shaped, with 5-6 costal setae, 2 basal group setae, 2 submarginal setae, marginal vein with 5 long and stout setae along the anterior margin, 2 large setae at its base and 6-8 smaller setae along its interior, alary fringe about 0.6 times as long as greatest width of disk. **Metasoma** - dorsum with imbricate lateral margins on tergites I-V, tergite VI and VII with weak striations; lateral margin of tergites II-V with 1 pair of long, slender setae, tergites V and VII with 1 pair of medial setae, lateral margin of tergite V with an additional pair of short setae, tergite VII with 2 pairs of long, slender setae; venter with 2 pairs of slender setae between the base of the metasoma and the ovipositor, ovipositor arising near the center of tergite III, 0.9 times as long as tibia of middle leg, valvulae III broad, 0.4 times as long as ovipositor.

#### Male (Fig. 7)

Length: Range = 0.56-0.70 mm, mean = 0.64 mm (based on 10 specimens)

Coloration: Head and mesosoma similar in coloration as that of female except only the basal quarter of each axilla is pale; metasoma dark brown; wings hyaline.

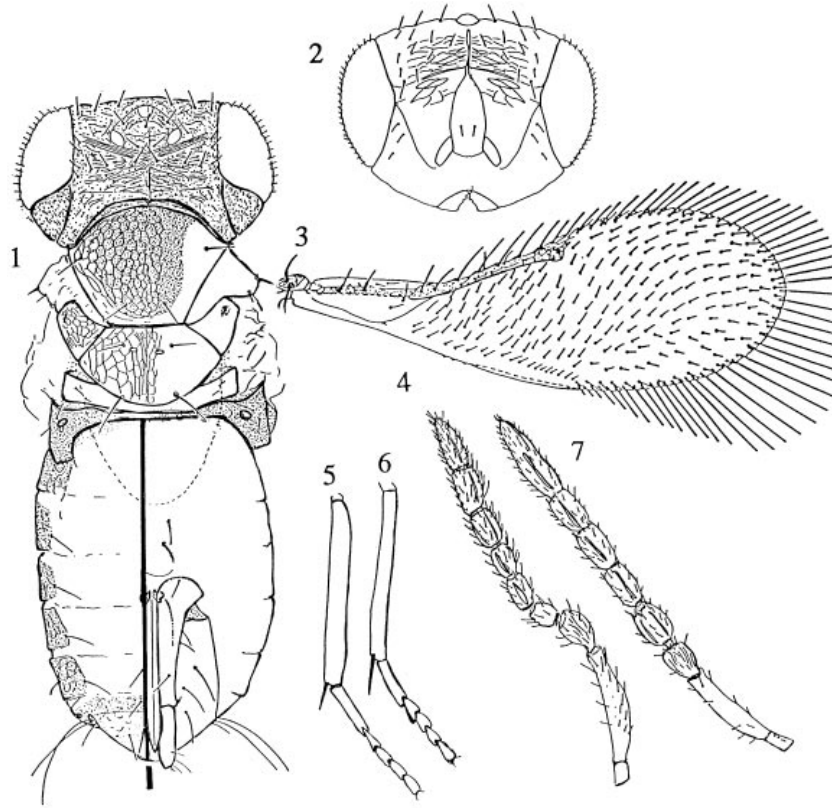
Structure: Similar to that of female except flagellar segments F1-F4 subequal in length and F5 and F6 fused.

**Distribution:** **Brazil.**

**Host:** *Bemisia tabaci* complex.

**Holotype:** Female, **Brazil:** Pernambuco, Olinda, 18 v 1991, F. D. Bennett, reared from *Bemisia tabaci* complex on *Chamaesyce* sp. deposited in the USNM. **Paratypes:** 39 females and 19 males with the same data as holotype. **Additional specimens:** 5 females and 2 males, Brazil, Pernambuco, Salvador, 22 V 1991, F. D. Bennett, reared from *Bemisia tabaci* complex on *Chamaesyce* sp. deposited as follows: U.S. National Museum, Washington, D.C. (USNM), Natural History Museum, London, UK (BMNH), Florida State Collection of Arthropods (FSCA), Aligarh Muslim University (AMU) and G.A. Evans personal collection.

**Comments:** *Encarsia polaszeki* Evans is most similar in structure and coloration to *Encarsia brevivalvula* Hayat and *Encarsia septentrionalis* Hayat, which were both



Figs. 1-7. *Encarsia polaszeki* (1-6 female, 7 male): 1) Habitus, with metasoma divided left side dorsum, right side venter; 2) head, frontal view; 3) fore wing; 4) antenna; 5) hind tibia; 6) middle tibia; 7) antenna.

described from India. *E. polaszeki* may be distinguished from *E. brevivalvula* by its more elongate third valvular segment and having only 2 pairs of setae on the mesoscutum (the third valvular segment of *E. brevivalvula* is very short and the mesoscutum has 4 pairs of setae). *E. polaszeki* differs from *E. septentrionalis* by its short F1 antennal segment which is only slightly longer than wide, and by having the distal submarginal vein seta as long as the proximal submarginal vein seta (the F1 segment of *E. septentrionalis* is approximately 2 times as long as wide, and the distal submarginal vein seta is much longer than the proximal submarginal vein seta).

*Etymology:* *Encarsia polaszeki* is named in honor and recognition of Dr. Andrew Polaszek for his contribution to the systematics of the genus *Encarsia*.

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BIOLOGY OF *PROPRIOSEIOPSIS ROTENDUS* (ACARI:  
PHYTOSEIIDAE) REARED ON *TETRANYCHUS URTICAE*  
(ACARI: TETRANYCHIDAE) OR POLLEN

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ABSTRACT

*Proprioseiopsis rotendus* (Muma) (Acari: Phytoseiidae) developed and oviposited when provided with all life stages of *Tetranychus urticae* Koch (Acari: Tetranychidae), and pollen of ice plant, *Malephora crocea* (Jaquin), live oak, *Quercus virginiana* Miller, or cattail, *Typha latifolia* (L.), as food sources under laboratory conditions of  $26 \pm 1^\circ\text{C}$  and 75-85% RH. Developmental times on the different foods were  $6.58 \pm 0.36$ ,  $8.17 \pm 0.92$ ,  $7.29 \pm 0.51$ , and  $7.41 \pm 0.89$  d (mean  $\pm$  SD) for females, and  $6.12 \pm 0.49$ ,  $7.96 \pm 0.94$ ,  $6.68 \pm 0.72$ , and  $6.75 \pm 0.60$  d for males, respectively. When *T. urticae* was provided as the food source, the highest net reproductive rate ( $R_0 = 23.69$ ), female longevity ( $45.7 \pm 6.26$  d), mean generation time ( $T = 19.54$ ), intrinsic rate of increase ( $r_m = 0.162$ ), and finite rate of increase ( $e^m = 1.176$ ) were obtained. Pollen of *M. crocea* was the superior food source with  $R_0 = 21.73$ , female longevity =  $44.1 \pm 13.3$  d,  $T = 22.57$ ,  $r_m = 0.136$ , and  $e^m = 1.46$ , followed by *Q. virginiana*. Cattail pollen was the least favorable food source tested with  $R_0 = 15.08$ , female longevity =  $56.1 \pm 4.83$  d,  $T = 23.96$ ,  $r_m = 0.113$ , and  $e^m = 1.120$ . The sex ratio was  $57 \pm 1:43 \pm 1$  (female:male) for all diets tested. Male longevity was  $47.3 \pm 6.08$  d when fed *T. urticae* compared with  $26.9-35.2$  d when fed pollen. *P. rotendus* adult females cannibalized newly hatched larvae. The mean daily ovipositional rate was 1 per d (max. 2) when fed on *T. urticae* or 0.5 per d

(max. 1) when fed on cattail pollen. Duration of the oviposition period was 5 times longer than the generation time (egg to egg) of *P. rotendus*.

Key Words: Biology, food range, developmental time, two-spotted spider mites, oviposition

#### RESUMEN

*Proprioseiopsis rotendus* (Muma) (Acari: Phytoseiidae) se desarrolló y ovopositó cuando fue alimentado con todos los estadios de *Tetranychus urticae* Koch (Acari: Tetranychidae), y polen de *Malephora crocera* (Jaquin), *Quercus virginiana* Miller, o *Typha latifolia* (L.) en condiciones de laboratorio de  $26 \pm 1^\circ\text{C}$  y 75-85% RH. Los tiempos de desarrollo en los diferentes alimentos fueron  $6.58 \pm 0.36$ ,  $8.17 \pm 0.92$ ,  $7.29 \pm 0.51$ , y  $7.41 \pm 0.89$  d (media  $\pm$  DT) para las hembras, y  $6.12 \pm 0.49$ ,  $7.96 \pm 0.94$ ,  $6.68 \pm 0.72$ , y  $6.75 \pm 0.60$  d para los machos, respectivamente. Cuando *T. urticae* fue suministrado como alimento, fueron obtenidos los más altos valores de tasa neta de reproducción ( $R_o = 23.69$ ), longevidad de la hembra ( $45.7 \pm 6.26$ ), tiempo promedio de generación ( $T = 19.54$ ), tasa intrínseca de incremento ( $r_m = 0.162$ ) y tasa finita de incremento ( $e^{rm} = 1.176$ ). El polen de *M. crocera* fue la fuente de alimento superior, con  $R_o = 21.73$ , longevidad de la hembra =  $44.1 \pm 13.3$  d,  $T = 22.57$ ,  $r_m = 0.136$ , y  $e^{rm} = 1.46$ , seguido por *Q. virginiana*. El polen de *T. latifolia* fue la fuente de alimento menos favorable, con  $R_o = 15.08$ , longevidad de la hembra =  $56.1 \pm 4.83$  d,  $T = 23.96$ ,  $r_m = 0.113$ , y  $e^{rm} = 1.120$ . La relación sexual fue  $57 \pm 1:43 \pm 1$  para todas las dietas probadas. La longevidad del macho fue  $47.3 \pm 6.08$  d cuando fue alimentado con *T. urticae* comparado con  $26.9-35.2$  d cuando fue alimentado con polen. Las hembras adultas de *Proprioseiopsis rotendus* canibalizaron las larvas recién eclosionadas. La tasa media ovoposicional diaria fue de uno por día (max. 2) cuando se alimentaron con *Tetranychus urticae*, o 0.5 (max. 1) cuando se alimentaron con polen de *Typha latifolia*. La duración del período de ovoposición fue 5 veces más larga que el tiempo de generación (de huevo a huevo) de *P. rotendus*.

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Thirty-eight species of phytoseiid mites have been reported on Florida citrus; however, the biology of only a few have been studied (Muma & Denmark 1970, Abou-Setta & Childers 1987, 1989, Caceres & Childers 1991, Yue et al. 1994, Fouly et al. 1995). *Proprioseiopsis rotendus* (Muma) (Acari: Phytoseiidae) was recorded from Florida citrus litter and bark (Muma & Denmark 1970) as well as from a wide range of plants in Arizona and Pennsylvania (Moraes et al. 1986).

Some phytoseiid mites (especially in the genus *Euseius*) can use alternative food sources such as pollen. This phenomenon increases species survival when animal prey are scarce. Such species are considered low density regulators, density independent, and have the ability of population increase in advance of their prey in late spring and early summer (McMurtry & Johnson 1965, Kennett et al. 1979, Abou-Setta & Childers 1987, Flechtmann & McMurtry 1992). To our knowledge, the biology of this genus has not been previously studied.

This study was conducted to determine the impact of different diets on the biology and life table parameters of *P. rotendus*. Two spotted spider mites, *Tetranychus urticae* Koch (Acari: Tetranychidae), and pollen of ice plant, *Malephora crocea* (Jaquin), live oak, *Quercus virginiana* Miller, or cattail, *Typha latifolia* (L.) were selected for this purpose.

*T. urticae* is a common phytophagous mite that feeds on more than 150 species of host plants (Jeppson et al. 1975). It is only an occasional pest on Florida citrus under



greenhouse conditions (Childers 1994). *M. crocea* pollen has been used as a diet for other phytoseiid mites in studies which were conducted in California and Florida (McMurtry & Johnson 1965, Abou-Setta & Childers 1987, Fouly et al. 1995). *T. latifolia* and *Q. virginiana* are annual and perennial plants, respectively, that occur in and around citrus groves in Florida. Their pollens may be natural food sources for *P. rotendus* during flowering.

This study was part of an ongoing effort to understand the biology of natural enemies associated with citrus in Florida.

#### MATERIALS AND METHODS

The *P. rotendus* culture was established from individuals collected on lower canopy leaves in a 'Pineapple' orange grove at Fort Ogden, DeSoto County, Florida in March 1993. The main culture was maintained on plastic arenas similar to ones used by Swirski et al. (1970). The rearing arena consisted of a water wick and a black painted plastic surface surrounded with a sticky barrier to prevent mites from escaping. Arenas were covered with plastic Petri dish bottoms to provide an enclosed environment about 2 cm high. A small piece of black construction paper was provided as arresting place and a few non-absorbent cotton fibers were attached to the water wick as egg deposition sites. The culture was provided with ice plant pollen obtained from the University of California-Riverside.

The food sources evaluated included all stages of *T. urticae* (on small pieces of Lima bean leaves), or pollen of *M. crocea*, *Q. virginiana*, or *T. latifolia*. Pollens were collected when available in the field and stored in the refrigerator at 5°C; small amounts were added to the arena as needed using a fine 5-0 sable hair brush.

The newly deposited eggs were transferred individually to 2.5 cm diam arenas. Newly hatched larvae were provided with one of the food sources listed. As new females matured, they were exposed to males from the same food group or from the main culture. A male was present with each female until her death.

The arenas were held in an environmental chamber at  $26 \pm 1^\circ\text{C}$  with a photoperiod of 12:12 (L:D). Relative humidity (75-85%) was measured at 1 cm height above the arena surface using a thermocouple for temperature and relative humidity (Abou-Setta & Childers 1987).

Individual development, survival, and egg deposition were observed daily. Life table parameters were calculated using a BASIC computer program (Abou-Setta et al. 1986).

#### RESULTS

##### Behavioral Observations

Rearing of *P. rotendus* was successful using the plastic rearing arena with either one of the pollens or motile stages of *T. urticae* as the food source. Eggs, larvae, nymphs and adults of *T. urticae* were consumed by adult *P. rotendus*.

*P. rotendus* eggs were whitish, crystalline, elongate-oval, and with a sticky surface when newly deposited. Their color changed to light reddish-brown before hatching. Larvae were whitish and slightly larger than the egg.

The protonymph and deutonymph stages were progressively larger than the larval stage with developing body color becoming increasingly brownish. Males were smaller than females and with the same brown coloration. Morphology of this species was considered by Fouly et al. (1994).

TABLE 1. EFFECT OF DIFFERENT FOOD SOURCES ON THE DEVELOPMENTAL TIME AND ADULT LONGEVITY OF PROPRIOSEIOPSIS ROTENDUS AT 26°C BY SEX.

Food Source	Sex	n	Developmental Time (days ± SD)						Adult Longevity
			Egg	Larva	Protonymph	Deutonymph	Total		
Tetranychus urticae	F	12	2.00 ± 0.21	0.76 ± 0.25	1.54 ± 0.33	2.38 ± 0.31	6.58 ± 0.36 c	45.7 ± 6.3 b	
Malephora crocea	F	15	2.87 ± 0.52	0.60 ± 0.21	2.27 ± 0.82	2.43 ± 0.98	8.17 ± 0.92 a	44.1 ± 13.3 b	
Quercus virginiana	F	14	2.32 ± 0.25	0.57 ± 0.18	2.29 ± 0.58	2.11 ± 0.45	7.29 ± 0.51 b	48.7 ± 6.0 b	
Typha latifolia	F	11	2.14 ± 0.32	0.55 ± 0.15	2.23 ± 0.75	2.50 ± 0.39	7.41 ± 0.89 b	56.1 ± 4.8 a	
Tetranychus urticae	M	9	2.00 ± 0.25	0.61 ± 0.22	1.39 ± 0.33	2.11 ± 0.22	6.11 ± 0.49 b	47.3 ± 6.1 a	
Malephora crocea	M	12	2.75 ± 0.54	0.67 ± 0.25	2.46 ± 0.50	2.08 ± 0.85	7.96 ± 0.94 a	26.9 ± 5.7 c	
Quercus virginiana	M	11	1.95 ± 0.55	0.55 ± 0.15	2.00 ± 0.45	2.18 ± 0.34	6.68 ± 0.72 b	35.2 ± 5.0 b	
Typha latifolia	M	8	2.06 ± 0.18	0.69 ± 0.26	1.81 ± 0.26	2.19 ± 0.26	6.75 ± 0.60 b	29.0 ± 5.0 c	

Means in each column followed by a different letter are significantly different,  $P < 0.05$  by SAS. Duncan test.

Mating took place just as a female reached maturity and continued for about 4 h. Mated females became more spherical as the egg developed compared to unmated females. No multiple matings were observed.

Eggs were deposited on the arena's surface close to the water wick, on the construction paper, or on the cotton fibers attached to the water wick. Egg deposition sites were the same regardless of food source.

*P. rotendus* was easily disturbed in the arena when exposed to bright light after darkness. Avoidance of light may contribute to their inhabiting the inner or lower canopy and surface debris on the ground.

Cannibalism was observed in crowded cultures, especially by adults feeding on newly emerged larvae. Feeding was not observed on any other stage.

#### Developmental Time and Adult Longevity

Type of diet tested and gender significantly affected individual developmental time and adult longevity. Mean male developmental time ( $6.95 \pm 1.0$  d) and longevity ( $34.20 \pm 9.46$  d) were significantly shorter than that for female ( $7.40 \pm 0.9$  d and  $48.25 \pm 9.5$  d respectively).

Both sexes developed significantly slower on ice plant pollen than other diets. Female mean developmental time,  $6.58 \pm 0.36$  d, was the shortest on *T. urticae* (Table 1).

Mean female longevity was significantly longer on cattail pollen than other diets ( $56.1 \pm 4.8$  d) while oviposition was the lowest (Tables 1 & 2).

Mean male longevity was significantly longer on *T. urticae* ( $47.3 \pm 6.1$  d) followed by live oak, cattail, and ice plant pollens (Table 1).

#### Life Table Parameters

Sex ratio was not affected by food source (Table 2). Survival curves of *P. rotendus* under laboratory conditions followed a type I pattern in which most eggs developed to maturity and death occurred gradually after an extended ovipositional period (Fig. 1,  $L_x$ ).

Maximum daily oviposition per female did not exceed 2 eggs per female per day ( $m_x$  value of 1.19 expected female progeny per female per day) when fed upon *T. urticae* (Fig. 1). Average daily oviposition ranged from a maximum of 1 egg per day when fed *T. urticae* to a low of 0.5 egg per day on cattail pollen.

TABLE 2. EFFECT OF FOOD SOURCE ON LIFE TABLE PARAMETERS OF *PROPRIOSEIOPSIS ROTENDUS* AT 26°C.

Food Source	Percentage Female (%)	F <sup>1</sup>	R <sub>0</sub> <sup>1</sup>	T (d) <sup>1</sup>	r <sub>m</sub> <sup>1</sup>	e <sup>mi</sup>
<i>Tetranychus urticae</i>	57	41.46	23.69	19.54	0.162	1.176
<i>Malephora crocea</i>	56	39.11	21.73	22.57	0.136	1.146
<i>Quercus virginiana</i>	56	29.16	16.33	21.41	0.130	1.139
<i>Typha latifolia</i>	58	26.05	15.08	23.96	0.113	1.120

<sup>1</sup>F, mean total fecundity (eggs per female); R<sub>0</sub>, net reproductive rate; T, mean generation time; r<sub>m</sub>, intrinsic rate of increase; e<sup>mi</sup>, finite rate of increase.

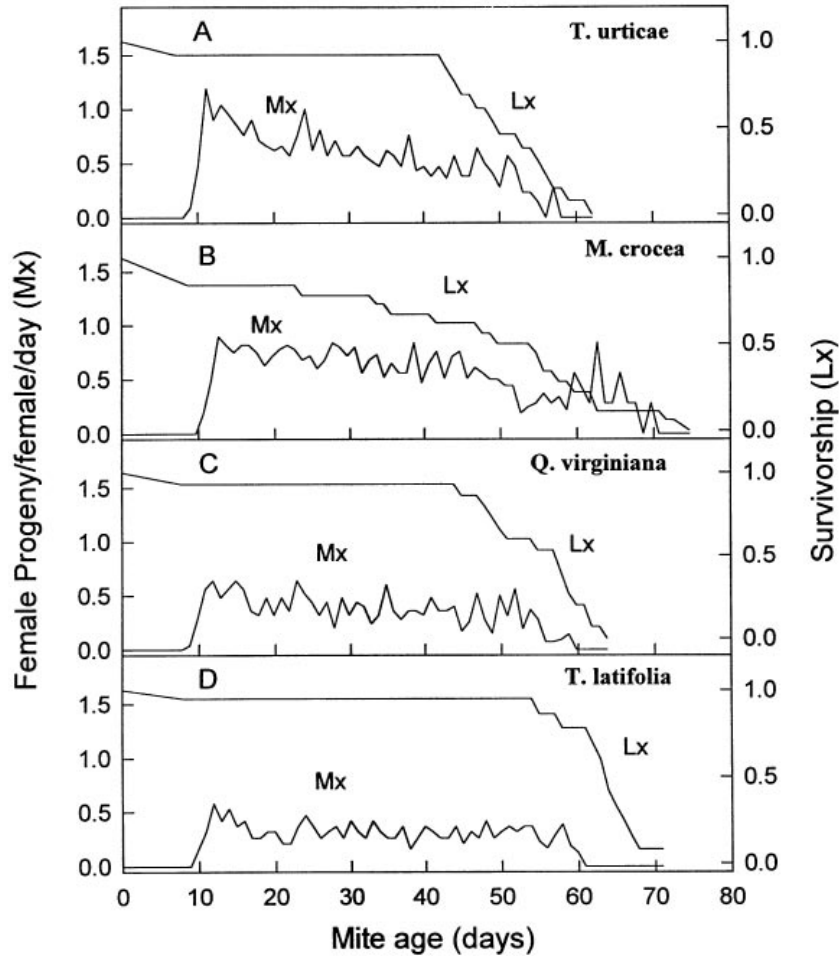


Fig. 1. Age-specific fecundity ( $M_x$ ) and survivorship ( $L_x$ ) of *Proprioseiopsis rotendus* feeding on different sources of food at 26°C. (A) *Tetranychus urticae* (mite); (B) *Malephora crocea* (pollen); (C) *Quercus virginiana* (pollen); (D) *Typha latifolia* (pollen).

Feeding on *T. urticae* resulted in the highest mean total fecundity of 41.46 eggs per female, net reproductive rate ( $R_0$ ) value of 23.69 expected females per female, and shortest mean generation time ( $T$ ) of 19.54 d. Feeding on pollen of different plant species resulted in lower  $r_m$  values with ice plant providing the maximum  $r_m$  (Table 2). A similar ranking for the diets was observed for *Typhlodromalus peregrinus* (Muma) (Fouly et al. 1995).

#### DISCUSSION

*P. rotendus* developed more slowly than most species of Phytoseiidae previously studied. This slow development may be a requirement to compensate for lower levels

of available food in both litter and the lower tree canopy than more arboreal phytoseiid species. Other phytoseiid species completed their development from egg to adult female at a constant temperature of 25-26°C within a range of 4-6 d (Sheriff 1982, Abou-Setta & Childers 1987, 1989, Bonde 1989, Caceres & Childers 1991, Fouly et al. 1995) compared with 6.58-8.17 d for *P. rotendus*.

The ovipositional period for *P. rotendus* was about 5 times greater than the generation time with a maximum ovipositional rate of 2 eggs per female per day. This ratio did not exceed 3-4 times for other phytoseiid species studied from Florida citrus (*Euseius mesembrinus* (Dean), *Galendromus helveolus* (Chant) and *T. peregrinus*) with maximum oviposition rates of 3-4 eggs per female per day at the same temperature (Abou-Setta & Childers 1987, Caceres & Childers 1991, Yue et al. 1994, Fouly et al. 1995). The number of eggs produced by a female over a period equal to one or two generation times was responsible for most of the calculated  $r_m$  value for mites and insects (Abou-Setta & Childers 1991). The longest survival of *P. rotendus* adult females occurred on cattail pollen, the least suitable food source.

#### ENDNOTE

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THE SEASONAL ABUNDANCE AND FEEDING DAMAGE OF  
*HYPSSIPYLA GRANDELLA* (LEPIDOPTERA: PYRALIDAE) IN  
SEED CAPSULES OF *SWIETENIA MAHAGONI* IN FLORIDA

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ABSTRACT

Larvae of *Hypsipyla grandella* attacked the seed capsules of West Indies mahoganies, *Swietenia mahagoni* Jacquin, in spring (March - April) after the capsules dehisced and the seeds were exposed, which occurred prior to flushing. One to 5 larvae occurred per capsule. The seeds apparently were a preferred food source and 50-96% of the seeds in capsules examined in June were damaged by larvae. Seed capsules during their period of expansion from early summer to winter were virtually free of borer attack, and during this period neither hardened-off shoots nor persistent capsule cores from previous seasons served as food sources for more than a few larvae. The hardness of the capsule valves is apparently a factor in preventing penetration by the larvae. Although the persistence of seeds in the capsules is transitory, and the availability of capsules more limited and more variable than that of shoots, the seed capsule contents appeared to be preferred as a food source, as higher percentages of dehisced seed capsules than new shoots were attacked when both were simulta-

neously available. The damage by *H. grandella* to mahogany seeds impacts regeneration of this tree species.

## RESUMEN

Las larvas de *Hypsipyla grandella* atacan a las cápsulas de las semillas de la caoba de las Indias Occidentales, *Swietenia mahagoni* Jacquin, en la primavera (marzo-abril) cuando éstas se abren y las semillas están expuestas, lo cual ocurre antes del brote de nuevas hojas. De una a cinco larvas se encontraron por cápsula. Las semillas aparentemente fueron la fuente de alimento preferida. El 50-96% de las semillas en las cápsulas examinadas en junio estuvo dañado por las larvas. Las cápsulas durante su período de expansión, a comienzos del verano, y hasta el invierno estaban virtualmente libres del ataque de los barrenadores. Durante este período tanto los brotes endurecidos como los corazones persistentes de las cápsulas sirvieron como alimento a de unas pocas larvas. La dureza de las valvas de la cápsula es aparentemente un factor de impedimento a la penetración por las larvas. A pesar de que la persistencia de las semillas en las cápsulas es transitoria, y la disponibilidad de las cápsulas es más limitada y más variable que la de los brotes, el contenido de la cápsula de las semillas parece ser preferido como alimento, debido a que más porcentaje de cápsulas abiertas que de nuevos brotes fueron atacados cuando ambos estaban simultáneamente disponibles. El daño causado por *H. grandella* a las semillas de caoba afecta la regeneración de este árbol.

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Two species of *Hypsipyla* are important pests of timber trees of the family Meliaceae. One species, *H. grandella* (Zeller), known as the mahogany shoot borer, is considered the major pest of mahoganies (*Swietenia* spp.) and cedros (*Cedrela* spp.) at the nursery and young plantation stage in the American tropics. The larvae kill the apical shoot, inducing a secondary shoot that results in a crooked stem and excessive side branching (Dourojeanni Ricordi 1963, Grijpma 1974, Howard & Meerow 1994, Lamb 1966, Yamazaki 1992). *Hypsipyla robusta* (Moore) plays a similar role on meliaceous trees in the Eastern Hemisphere tropics (Gray 1972). Research on the biology and control of *Hypsipyla* spp. was recently reviewed by Newton et al. (1993).

Most studies of the feeding habits of these insects have focused on injury to shoots, but both species also have been reported to infest seed capsules of meliaceous hosts (Beeson 1961, Betancourt 1987, Bruner 1936, Monte 1933, Roberts 1966, Solomon 1995, Tillmanns 1964, Wagner et al. 1991). Monte's (1933) observations indicated that *H. grandella* was highly adapted to utilizing seed capsules: larvae that hatched from eggs laid on green seed capsules of cedros penetrated into the interior of the fruit and fed on seeds. Before pupating, the mature larva made a hole in the capsule valve by which it later exited as an adult. Adults of *H. grandella* reared from larvae infesting seed capsules were larger than those obtained from shoots (Becker 1976), indicating the importance of fruits in the development of this insect. *Hypsipyla robusta* is listed as a pest of fruits of meliaceous timber trees in West Africa (Wagner et al. 1991). In northern India and Burma, where *H. robusta* attacks toon (*Toona ciliata* H. Roemer), it is known as the 'toon fruit and shoot borer' (Beeson 1961).

Some observations have been made on the seasonal occurrence of feeding on seed capsules by *Hypsipyla* spp. Hochmut & Manso (1975) reported that in Cuba *H. grandella* attacks seed capsules of meliaceous trees during the dry period when young shoots of these hosts are not available. In northern India, the first generation of the growing season of *H. robusta* feeds on flowers of *T. ciliata*, the second on seeds in the



green fruit capsule, and the remaining generations (third through fifth) in shoots of the current year (Beeson 1961). In Nigeria, *Hypsipyla* sp. feeds on flowers of African mahogany, *Khaya ivorensis* A. Chev., from September to November, on seed capsules from November to February, and on shoots during the remainder of the growing season (Roberts 1966).

In southern Florida, the host of *H. grandella* is the West Indies mahogany, (*Swietenia mahagoni* [Linnaeus] Jacquin), which is native to Florida and is the only representative of Meliaceae native to the continental United States (Harlow & Harrar 1968, Pennington 1981). Although the insect attacks exotic species of Meliaceae, few of these are planted in southern Florida. Attacks on shoots of West Indies mahogany by *H. grandella* peak in May of each year, coinciding with the spring flush (production of new leaves and shoots) at the beginning or just before the advent of the wet season (June - September). During the remainder of the wet season, shoot production is sporadic and attack by *H. grandella* diminishes greatly, and is virtually nil during the dry season (October - May) (Howard 1991). This paper elucidates the seasonal abundance and feeding damage of *Hypsipyla grandella* (Lepidoptera: Pyralidae) in seed capsules of *Swietenia mahagoni* in southern Florida.

#### METHODS AND MATERIALS

The study was conducted during the period March 1995-January 1996. We identified the immature stages of *H. grandella* by diagnostic characters illustrated by Ramirez Sanchez (1964). We collected 20 larvae from different seed capsules and reared them to the adult stage on excised mahogany shoots with their bases in water or on mahogany seeds. We compared the specimens of adults with illustrations in Becker 1976, Grijpma 1974, Ramirez Sanchez 1964, and Roovers 1971. For confirmation of the identification, 4 of the specimens of adults were examined and identified as *H. grandella* by J. B. Heppner (Florida State Collection of Arthropods, Gainesville).

All trees in this study were 5-20 year old West Indies mahoganies planted on the Fort Lauderdale Research & Education Center. A total of 338 trees of this species are planted on this site.

Physical characteristics of the seed capsules and seeds that might influence larval feeding were observed. The length of time that the winged seeds persisted on the capsule and thus remained available as food for larvae was determined. Capsules were marked with the date that they opened and observed on April 17 and 24 for the numbers of seeds persisting and the numbers that had been shed as indicated by placental scars.

The thickness of capsule valves were measured at their midpoints with calipers in April and in October. The diameters and lengths of capsules were measured in July, October and January. In April and October, the resistance to penetration of seed capsules and their contents was determined with a Model RP-3T Missouri Type Rind Penetrometer (Alan Machine Co., Ames, Iowa 50010). Points of penetration included seeds, cores, and valves at midpoint and seams between valves. A common bottle cork (processed bark of *Quercus suber* L.) was used as a standard.

The first field observations in this study were made on March 29, 1995, prior to the spring flush. Twenty dehisced capsules, all of which showed larval damage (gallery plus frass typical of this species), were removed from trees and dissected and examined to confirm the presence of larvae of *H. grandella* and to determine where the larvae had fed.

Between April 4 - May 8, three trees, all about 6 m in height, were selected arbitrarily among those bearing unopened seed capsules. These trees were observed every 1-3 days to determine the dates of flushing, dehiscence of the capsule, and initial dam-

age to shoots and/or seed capsules. The dates that the capsules dehisced and that borer damage was first evident were written on 2 cm × 9 cm aluminum tags fixed to the peduncles. On May 3 and May 8 the percentage of marked seed capsules and of 50 randomly selected new shoots with borer damage was determined and all marked seed capsules (n = 26) were dissected and examined for larvae.

From May 1995 - January 1996, West Indies mahogany trees on the Research Center continued to be examined frequently for evidence of damage to seed capsules or shoots. In January 1996, a total of 400 capsules of the current season were clipped from trees and examined in the laboratory for evidence of borer damage. One hundred of these were examined with a 10 × hand lens for eggs of *H. grandella*. We had previously observed that cores of a large portion of the seed capsules of West Indies mahogany persist after valves and seeds have been shed and may remain on the trees for up to 2 seasons. To determine whether these served as food sources for *H. grandella* larvae in winter, 78 cores of the past summer's and 22 of the previous year's seed capsule which remained on trees were examined. In addition, the stems and branches of 75 trees < 2 m in height were examined closely for larvae or damage by them.

#### RESULTS

Seed capsules of West Indies mahogany (Fig. 1) develop from small (5 mm diam) flowers that bloom in June-July in Florida (Howard et al. 1995), expanding rapidly in summer. By the end of July the capsules were about half their mature size of about 65 mm × 75 mm, which they reached in January when they began to dehisce. *Hypsipyla grandella* rarely penetrated the capsules until they dehisced, after which they readily attacked them. The relatively thick, hard capsule valves are no doubt a factor in preventing most *H. grandella* larvae from penetrating them to reach the food-rich seeds. Newly dehisced valves were a mean of 8.9 mm thick (range 7-15 mm, n = 20) measured at midpoint and 5 -10 × harder than the cores, as measured by penetrometer readings. The resistance to penetration of the cores was similar to that of common bottle cork, while that of the seeds was lower (Table 1).

In both October and April, sites along the seams at the juncture of valves were generally 1/3 to half as resistant as the valves at midpoint. However, in April about 30% of the sites along the seams had about the same resistance as seeds, *i. e.*, about 10% the resistance of tissue at valve midpoints, indicating that the seams were weakening as the capsules dehisced. However, with the exception noted below, larvae did not utilize this potentially easy entry point.

On March 29, 1995, the first day of field observations, about 30 trees had seed capsules. Only a small portion of the total capsules had dehisced and all these had *H. grandella* damage. Of the 20 of these that were sampled, 11 were infested with larvae and 2 contained cocoons of this species. There was never more than one late-instar larva per capsule, but earlier instars occurred up to 5 per capsule. The 9 capsules that did not contain *H. grandella* immature stages showed evidence of their damage, but the larvae had left.

One predehisced mature capsule observed in April had a hole along a seam. The capsule was dissected and found to contain a larva of *H. grandella*. In August, a young capsule 42 × 44 mm had a hole interior to the margin of the valve about 3.6 mm in diam with frass identifiable as that of *H. grandella*. The hole was filled with the gummy exudate characteristic of wounds in mahoganies. Dissection of the capsule revealed a late instar of *H. grandella*.

West Indies mahogany seeds persisting in capsules apparently were a preferred food source for *H. grandella* larvae. They usually bored through the layers of seed wings and, upon reaching the core, attached themselves between the core and the



Fig. 1. Parts of seed capsules of *Swietenia mahagoni*; A) Dehisced capsule with damage and frass of *H. grandella* larvae; B) Dehisced insect-free capsule (s, seeds, which are born on a central core; v, valves); C) Capsule in initial stage of dehiscence; D) Core after seeds have been shed, with galleries made by *H. grandella* larvae.

seeds, hollowing out the seeds from their proximal sides so that from the outside of the capsule the larvae were not visible and the seeds appeared sound. Early and late instars were observed feeding on seeds, but only late instars were observed in cores, suggesting that they fed on seeds first and then bored into cores.

The seeds are susceptible to attack by *H. grandella* only as long as they persist in capsules, and this parameter is highly variable. Five of the marked capsules shed most of their 50-80 seeds in a few days. Others shed seeds more gradually. In 3 capsules observed, all of the seeds persisted 18 days after they had dehisced, in spite of winds on one day estimated at up to 25 kph that buffeted the tree branches and caused the seeds to flutter. Once larvae began to attack seeds, they enveloped them in webbing, which prevented them from falling from the capsules.

Most seed capsules on the 3 sample trees dehisced on different days between March 31 - April 13 and were attacked by *H. grandella* larvae prior to flushing of these trees. Flush occurred during the period April 14-19. *Hypsipyla grandella* larvae apparently entered 2 of the capsules the day that these split open as evidenced by frass issuing from between the seeds. In the other 24 capsules, frass was first seen 7 to 30 days after the capsules opened.

Higher percentages of dehisced seed capsules than new shoots were attacked when both were simultaneously available. When counts were made on May 3, 70 - 100% of the dehisced capsules on the 3 sample trees (n = 26), compared to 14 - 22% of the new shoots (n = 150), had been attacked. A week later, there was a slight increase in the percentage of dehisced capsules attacked but no discernible increase in shoots attacked.

Capsules (n = 22) dissected on June 5 revealed that larvae of *H. grandella* had fed on seeds and excavated galleries in the cores of almost all capsules and were still present in 81.8% of them. Six to 37 seeds persisted per capsule, but 50-96% of the

TABLE 1. MEAN PENETROMETER READINGS (KG PRESSURE) ON PARTS OF SEED CAPSULES AND SEEDS OF WEST INDIES MAHOGANY AND ON COMMON CORK FOR COMPARISON.

Plant Part	N	Mean $\pm$ SD
Common cork	10	3.7 $\pm$ 0.1
April, dehisced capsules:		
Valves, midpoints	25	16.4 $\pm$ 3.7
Valves, seams	15	9.3 $\pm$ 4.5
Cores	20	3.9 $\pm$ 0.6
Seeds	10	1.6 $\pm$ 0.3
October, predehisced capsules:		
Valves, midpoints	11	13.5 $\pm$ 2.9
Valves, seams	11	9.7 $\pm$ 4.3

seeds in different capsules were damaged by larvae, either with large holes or completely hollowed out from the inside. A maximum of 5 larvae were found in one capsule, these being of early instars. Most capsules had 1 or 2 larvae. A single mature (fifth instar) larva was found in each of nine capsules. Two capsules had pupae. Capsules (n = 4) dissected on July 31 were similarly damaged, and one contained a single pupa of *H. grandella*.

Of the 400 capsules examined in January, a total of 5 capsules had dehisced. Larvae of *H. grandella* were in 4 of the dehisced capsules and in one predehisced capsule, distributed as follows: Two capsules had apparently been dehisced at least since December and each harbored a fifth instar *H. grandella* larva. Two dehisced capsules each harbored 1 early instar of *H. grandella*. There were no entrance holes in the valves, indicating that the larvae had entered after dehiscence of the capsule. An early instar larva was on the outside of a predehisced capsule. In the laboratory, this larva bored into the valve during the next 4 days, but eventually died. There were 2 capsules with superficial feeding scars that may have been caused by *H. grandella* larvae, but larvae were not present. Two capsules had initial entrance holes with pitch tubes, which may have expelled attacking larvae.

With the exception noted, neither eggs nor borings by larvae were observed in the predehisced capsules in January. At this time, the previous summer's leaves persisted on the West Indies mahogany trees and no new leaves or shoots were produced. There was no evidence of shoot or stem attack by *H. grandella*.

Also in January 1996, 69.2% of the past summer's and 90.9% of the previous year's cores had borer damage. Many of the cores of the capsules of the current year contained deteriorated silk and frass that had persisted since the spring and one had an empty pupal case of *H. grandella*. However, no live immature *H. grandella* were found in the cores. The galleries of many of them were occupied by other arthropods, mostly predators, including *Pseudomyrma* sp. (Hymenoptera: Formicinae) workers with brood, other ant species, wasps, and spiders. The persistent cores were dry and deteriorated and of doubtful value as a food source for *H. grandella*, which is adapted to feed on living plant tissue.

None of <2 m trees (n=75) closely inspected in January had *H. grandella* larvae or damage to stems.

## DISCUSSION

Our observations indicate that *H. grandella* larvae attack seed capsules in spring with dehiscence of the capsules and exposure of the seeds, which occurs prior to flushing. About 70-100% of the open capsules on different trees are attacked. The larvae hollow out seeds and penetrate the core. This insect's apparent preference for seed capsules is consistent with Becker's (1976) observation that larvae reared from capsules are larger than those reared from shoots. When the trees flush, < 25% of the shoots on the same trees are attacked. Larvae rarely penetrate the capsule valves, probably because of the thickness and hardness relative to that of the seeds and capsule cores. Seed capsules of the current year are virtually free of borer attack during their period of expansion from spring to early winter, as are persistent capsule cores from previous seasons. We have occasionally found larvae in shoots in late summer, but they apparently are very scarce to absent from this host plant from midsummer to the next spring flush. The question of where and under what conditions *H. grandella* passes this period in Florida remains a gap in our knowledge of their life history. Gravid females are presumably present and either abundant or efficient enough to find the few dehisced seed capsules present during January, more than 3 months before an abundant supply of dehisced capsules and new shoots are available in April. Meliaceous trees other than *S. mahagoni* are ruled out as alternate hosts, because they are extremely rare in southern Florida.

Both excised shoots and seeds of West Indies mahogany support the development of larvae to maturity in the laboratory. Although in the field a higher percentage of capsules than shoots were attacked and apparently are a richer food source, their availability is less certain than shoots. Young trees less than 5 years old do not produce seed capsules, and mature trees produce many more shoots than capsules. Annual production of seed capsules is highly variable. We have routinely observed that mature West Indies mahoganies produce from 0 to about 50 seed capsules compared to many hundreds of shoots. A maximum of about 300 capsules was observed on a tree in 1995.

The results of this study indicate that *H. grandella* may severely restrict the regeneration of West Indies mahogany in Florida. Where seed production is important, West Indies mahogany capsules should be protected against *H. grandella* attack, but methods have not been investigated.

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PERSISTENCE AND CONTAINMENT OF *METASEIULUS OCCIDENTALIS* (ACARI: PHYTOSEIIDAE) IN FLORIDA: RISK ASSESSMENT FOR POSSIBLE RELEASES OF TRANSGENIC STRAINS

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ABSTRACT

*Metaseiulus occidentalis* (Nesbitt) is a phytoseiid mite which is commercially available as a biological control agent of spider mites. Genetic manipulation of this phytoseiid species has yielded transgenic strains, but none have been released into the environment. Previous data suggested that *M. occidentalis* could not survive the wet, humid summers in Florida. A non-transgenic strain of *M. occidentalis* was released into field plots in Gainesville on soybean plants infested with the two-spotted spider mite, *Tetranychus urticae* Koch. Populations were monitored from April-October 1994, and weather data were gathered at the release site. Permethrin-treated barrier rows were monitored to determine if the mites dispersed outside the plots, and aerial dispersal was monitored with sticky traps. Predator and spider-mite populations repeatedly crashed during the summer months, and population growth was negatively correlated with rainfall. CLIMEX, a population growth model which uses climatic factors to determine whether a given poikilothermic species can colonize and persist in new geographic areas, also indicated that *M. occidentalis* cannot persist through the wet season in Florida, although it may be able to establish and persist through the fall, winter and spring months.

Key Words: Spider mites, phytoseiid mites, genetic improvement, climate models, biological control, risk assessment

RESUMEN

*Metaseiulus occidentalis* (Nesbitt) es un ácaro fitoséido disponible comercialmente como agente de control biológico de ácaros fitófagos. La manipulación genética de esta especie de fitoséido ha producido colonias transgénicas, pero ninguna ha sido liberada al ambiente. La información previa sugiere que *M. occidentalis* no podría sobrevivir el verano lluvioso y húmedo de la Florida. Una colonia no transgénica de *M. occidentalis* fue liberada en parcelas de campo en Gainesville en plantas de soya infestadas con el ácaro de dos manchas, *Tetranychus urticae* Koch. Las poblaciones fueron muestreadas desde abril hasta octubre de 1994; los datos climáticos fueron colectados en el sitio de liberación. Se muestrearon las hileras de barrera tratadas con permetrina para determinar si los ácaros se dispersaron fuera de las parcelas, y la dispersión aérea fue monitoreada con trampas pegajosas. Las poblaciones del depredador y del fitófago colapsaron repetidamente durante los meses de verano; además, el crecimiento de la población estuvo correlacionado negativamente con la lluvia. CLIMEX, un modelo de crecimiento poblacional que usa factores climáticos para determinar cuando una especie poikilotérmica puede colonizar y persistir en nuevas áreas geográficas, indicó también que *M. occidentalis* no puede persistir durante la estación de lluvias en la Florida, aunque podría establecerse y persistir durante los meses de otoño, invierno y primavera.

The western predatory mite, *Metaseiulus* (= *Typhlodromus* or *Galendromus*) *occidentalis* (Nesbitt) (Acari: Phytoseiidae), is an obligatory predator and successful biological control agent of spider mites (Tetranychidae) in vineyards and apple and almond orchards in the western United States (Hoyt 1969, Flaherty & Huffaker 1970, Hoy 1985a). *M. occidentalis* is marketed commercially as a biological control agent and is recognized as having a potentially world-wide role in integrated spider mite control programs (Hoy 1985a,b).

The biology and bionomics of *M. occidentalis* are well known. Numerous life-table studies have examined the effects of different temperatures and prey availability on *M. occidentalis* (Laing 1969, Tanigoshi et al. 1975, Bruce-Oliver & Hoy 1993). Hoy et al. (1985a) demonstrated that hungry adult females display an explicit aerial dispersal behavior in low to moderate wind speeds. Well-fed mites do not show aerial dispersal behavior, indicating that food availability may be a component in stimulating aerial dispersal.

Muma & Denmark (1970) do not list *M. occidentalis* among the species of phytoseiid mites occurring in Florida, and Denmark (Personal communication) indicated no subsequent records of *M. occidentalis* are available to indicate this species has since established in Florida, despite numerous commercial importations. Hoying & Croft (1977) examined literature and museum specimens and, aside from one report from eastern Wisconsin and one specimen from southern Alberta, Canada, found no reports of *M. occidentalis* occurring east of the Rocky Mountains.

A number of phytoseiid species, including *M. occidentalis*, have been genetically manipulated via artificial selection to produce pesticide-resistant or non-diapausing strains (Hoy 1992). Genetic manipulation using recombinant DNA techniques could improve the efficiency of genetic manipulation of biological control agents by reducing the time required to identify variability upon which to select, and by providing genes which do not occur naturally in the species. Presnail & Hoy (1992) used a maternal microinjection technique to transform *M. occidentalis* with a plasmid containing the  $\beta$ -galactosidase gene (*lac Z* construct) from *Escherichia coli* under the control of the *Drosophila melanogaster* Meigen heatshock 70 promoter. Because so much is known about the biology of *M. occidentalis*, it is an ideal arthropod to use for evaluating the risks of releasing transgenic arthropods into the environment.

The U.S. Department of Agriculture, Agricultural Biotechnology Research Advisory Committee (ABRAC) (1991) provides guidelines for risk assessment in transgenic releases. Our tests aim to answer the following questions that are raised in the ABRAC guidelines: 1) What is the organism's potential to establish itself in the accessible environment? 2) What is the potential for monitoring and control in the accessible environment?

If *M. occidentalis* cannot permanently establish in Florida due to its inability to survive the unfavorable summer climate, then Florida could be an ideal site for experimental transgenic releases. Experimental plots could be maintained throughout the favorable fall, winter, and spring months, with the summer climate serving as an additional safe-guard against accidental establishment. This study examines the ability of non-transgenic *M. occidentalis* to persist in Florida through the unfavorable wet summer months in experimental field plots. The plots were also designed to determine whether *M. occidentalis* can be contained within the experimental plots and kept from dispersing aerially. In addition, a climatic model is used to determine the likelihood of *M. occidentalis* establishing and persisting in Florida.



## MATERIALS AND METHODS

## Persistence

Sixty to seventy-five pinto bean seeds were planted (3:2 potting soil to vermiculite mixture) in eight liter pots. A total of 75 pots were arranged into five plots, with each plot containing three rows of five pots. Plots were laid out on an east-west axis at a University of Florida field station in Gainesville, FL. The rows were spaced 60 cm apart, and the plots were placed 152 cm apart (Fig. 1). Single pots of beans were placed in line with each of the rows between each of the plots to act as "trap" plants between the plots. On March 27, 1994 (Julian day 86; all subsequent dates refer directly to days of the Julian calendar), when the bean plants had reached the 3 to 5-leaf stage, the center row of each plot was infested with *Tetranychus urticae* (Koch) by laying cut foliage containing *T. urticae* atop the uninfested potted plants. As the cut foliage dried, the *T. urticae* adults transferred to the green foliage. On day 92, a 10-leaf subsample was taken from each plot to determine the approximate density of *T. urticae*. Three paraffin-coated paper disks containing adult *M. occidentalis* females were spaced equally along the center row of each plot to approximate a 20:1 spider mite to predator ratio.

On day 113, two pots were removed from each row and replaced with two new pots of bean plants. The foliage from the pots that were removed was cut and laid over the new plants to allow the predators and *T. urticae* present on the cut foliage to transfer to the new foliage. From that point, two new pots were cycled into each row every two weeks, and the pots were rearranged so that the oldest pot was in the center of each row, flanked by the two newest pots. All new plants were sprayed with carbaryl (1.1 kg a.i./ha) one day before placement into the field to eliminate other predators and herbivores. The strain of *M. occidentalis* used (COS) is resistant to carbaryl, sulfur, and organophosphorus insecticides (Hoy 1984).

Plots were sampled once weekly starting on day 99. Five leaves were sampled from each plant for a total of 25 leaves per row per plot. Each 25-leaf sample was placed into a paper bag, chilled and taken to the laboratory, where a mite brushing machine was used to brush the mites from each 25-leaf sample onto a glass plate. Numbers of all stages of *M. occidentalis* and *T. urticae* were counted under a dissecting microscope, and the mean number of mites per leaf was determined for each row in each plot.

Following a population crash, plants were re-infested with spider mites on day 142, and *M. occidentalis* was added again on day 148. Sampling resumed on day 155. Additional *T. urticae* and *M. occidentalis* were added on day 197, and *T. urticae* only were added on day 225. Weekly sampling continued through day 281 (October 8, 1994). To determine if mite populations would rebound on their own, a subset of two pots per plot were removed on day 197 and replaced with new bean plants. The removed pots were placed in a new location with one new pot for each two pot subset. These five new plots were not re-infested, but fresh pots were cycled in each week.

## Containment

The two outside rows of each plot, as well as the trap plants between the plots were sprayed with permethrin (0.06 kg a.i./ha) every two weeks starting on day 92. *T. urticae* is unaffected by permethrin at this rate, but the *M. occidentalis* strain used in this study is highly susceptible to this insecticide. Thus the outside rows of each plot were designed to act as barrier rows to dispersal by *M. occidentalis*.

Twenty-two 1.8 m cedar stakes were spaced at 1.5-m intervals around the plot (Fig. 1). Each stake held three 185 mm × 78 mm plexiglass plates coated with a thin



washing detergent to loosen material stuck to the grease. The slurry from the trays was then filtered through a fine mesh screen, and the contents were examined under a dissecting microscope to determine if any *M. occidentalis* were stuck to the plates, which would indicate that *M. occidentalis* was dispersing aerially.

#### Weather Data

Meteorological data was gathered from the site by a Campbell CM-10 datalogger and weather station (Campbell Scientific, Logan, UT). Temperature, precipitation, relative humidity, and wind speed and direction were recorded every 10 min. Maximums, minimums and totals for each 24-h period were compiled. Data were downloaded roughly once a week.

#### The CLIMEX Model

A computer climate modeling system was used to determine the likelihood of *M. occidentalis* surviving and establishing in Florida. CLIMEX is a computerized climate matching system which uses biological data to predict the potential relative abundance and distribution of poikilothermic animals in a given geographic area (Sutherst & Maywald 1985). The CLIMEX model utilizes climatic data from around the world, along with what is known of the biology and distribution of a given species to determine that species' potential to survive and proliferate in a given environment.

The CLIMEX model calculates an Ecoclimatic Index (EI) which utilizes weekly temperature, moisture, and daylength indices, and yearly cold, dry, heat, and wet stress indices. The EI, scaled between 0 and 100, is determined by the following equation:

$$EI = 100(\Sigma GI)/52 \times [(1-CS) \times (1-DS) \times (1-HS) \times (1-WS)]$$

where CS, DS, HS, and WS are yearly cold stress, dry stress, heat stress, and wet stress indices scaled between 0 and 1. GI is the weekly population growth index, which is the product of the weekly temperature, moisture, and daylength indices.

The derivations of these indices are described in more detail in Sutherst & Maywald (1985).

Optimal and upper and lower threshold temperatures for *M. occidentalis* population growth were obtained from the literature (Tanigoshi et al. 1975) and used in the model. Unknown moisture parameters and threshold indices were then systematically altered until a distribution map approximating the known distribution of *M. occidentalis* in western North America was achieved (Hoying & Croft 1977). The model then graphed the predicted population growth curves for *M. occidentalis* populations in Jacksonville and Tampa, FL. These cities were chosen as they are the two cities closest to Gainesville that are included in the model's meteorological database.

## RESULTS

#### Persistence

Both species remained in the plots at relatively stable levels (at a roughly 28:1 prey:predator ratio) through the month of April (Fig. 2). The mean densities of *M. occidentalis* and *T. urticae* for each sampling date crashed at the beginning of May (day 127), corresponding to a storm on day 124 that dumped 80.7 mm of rain in 5 h. Spider mite populations were reduced four-fold, to just over 1.5 *T. urticae* per leaf. Predator

mite densities were cut in half, lowering the prey:predator ratio. The food supply for *M. occidentalis* continued to decline over the subsequent 7-d period, and only two male *M. occidentalis* found in the entire 125 leaf sample from all five plots on day 141.

Reinfestation of the plots in late May was done with higher densities of both mite species, although the prey:predator ratio was maintained roughly the same as in the first infestation. Between days 155 and 162, *T. urticae* populations declined 55%, while *M. occidentalis* populations declined 65% (Fig. 2). Sampling on day 162 occurred in a light rain, and 26 mm of rain fell that afternoon, immediately before the sample was taken. More *T. urticae* were added to each plot on day 164, resulting in the population upswings seen for both species in the samples taken on day 169.

Population trends of both species were negatively correlated with increasing rainfall ( $df = 16$ ,  $p = 0.0036$  [Fig. 3A],  $df = 16$ ,  $p = 0.0015$  [Fig. 3B]). Percent population change was not calculated for those weeks in which more mites were added to the plots. The subplots that were started on day 170 showed that neither mite population would rebound without reinfestation (Table 1). No *M. occidentalis* were found in this subplot after day 211, although some *T. urticae* persisted at very low densities through the rest of the sampling dates.

#### Containment

A total of five *M. occidentalis* were found on the 66 plexiglass plates designed to detect aerial dispersal. The mites were found only on two of the 27 sampling dates (Table 2). Three were found on plates on the north side of the plot at the 43 cm level on day 211, and two were discovered on plates on the day 260 sampling date; one on the north

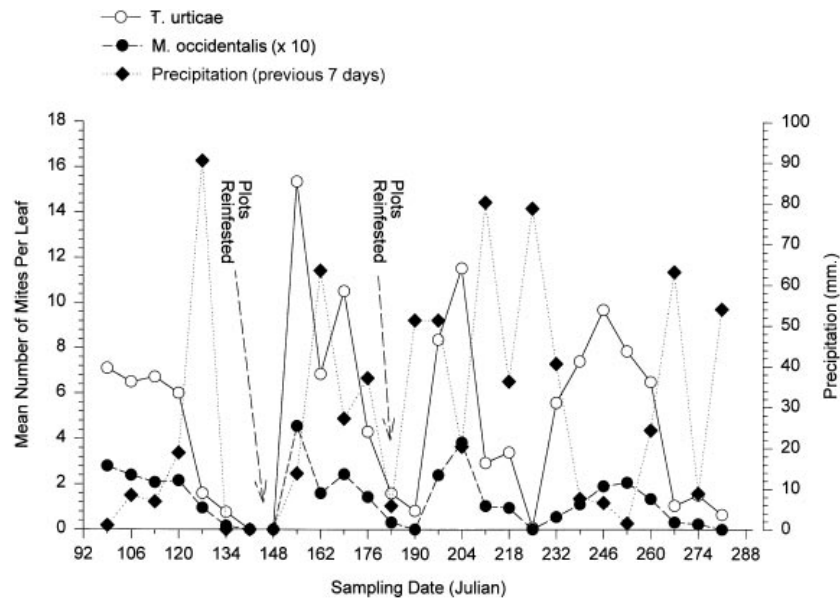


Fig. 2. Mean densities of *M. occidentalis* and *T. urticae* and cumulative total rainfall for each sampling date.

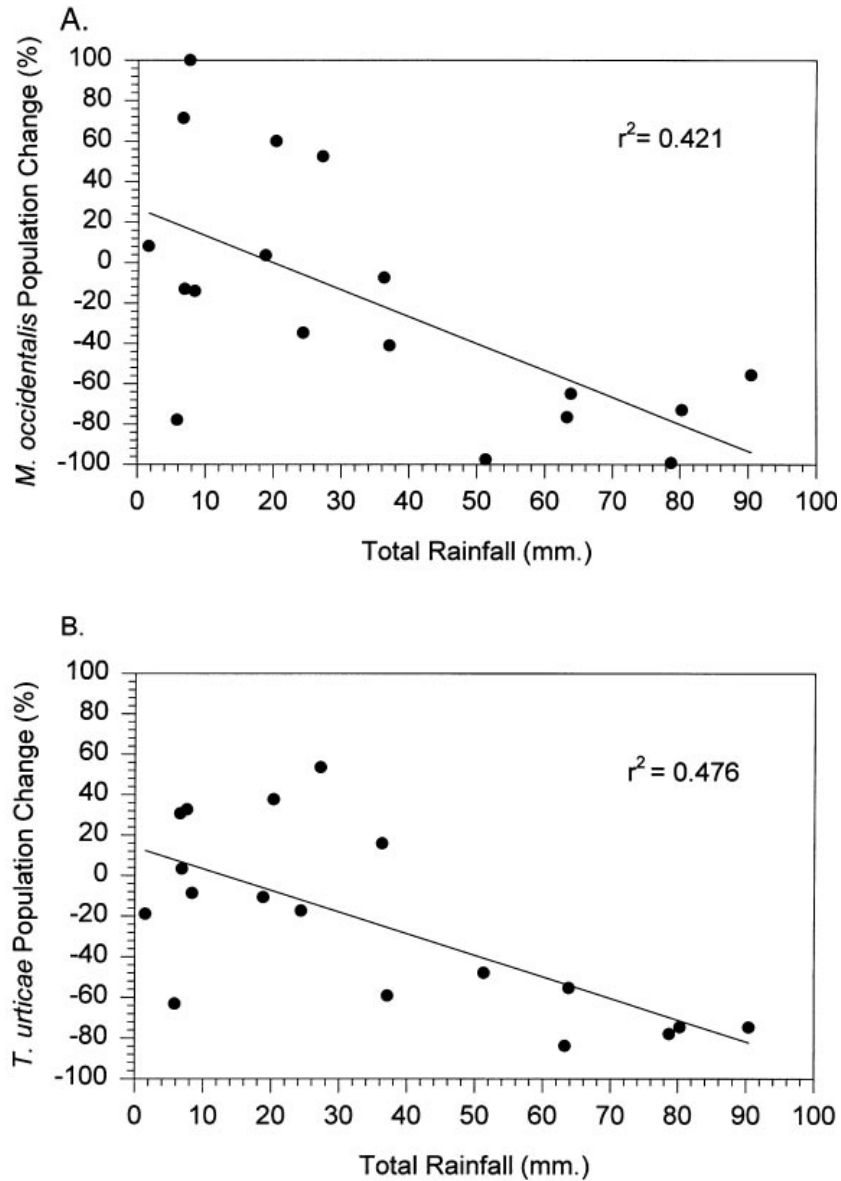


Fig. 3. A. Percent population change of *M. occidentalis* as a function of total rainfall in Gainesville, FL from Julian day 99, 1994 to Julian day 281, 1994. B. Percent population change of *T. urticae* as a function of total rainfall. Population change is calculated weekly, excluding those weeks that mites were released into the plots.

TABLE 1. SUMMARY OF *T. URTICAE* AND *M. OCCIDENTALIS* POPULATIONS FROM SUBPLOTS ESTABLISHED JULY 16, 1994 (JULIAN DAY 170).

Sampling Date (Julian)	Mean <i>M. occidentalis</i> per Leaf	Mean <i>T. urticae</i> per Leaf
204	0	1.25
211	0.008	0.86
218	0	0.27
225	0	0.54
232	0	1.01
239	0	0.66
246	0	0.42
253	0	0.20
260	0	0.49
267	0	0.25
274	0	0.12
281	0	0.44

side of the plots at the 54 cm high level, and one on the east side at the 110 cm high level. Spider mites were found on the plates on all sample dates. The prevailing wind direction at the site is from the south-southwest, although easterly winds prevailed during some periods of stormy weather. Calculating the area along each side and each end of the plot to a height of 1.8 m (the height of the stakes holding the plexiglass plates) yields a total area of 61.32 m<sup>2</sup> around the periphery of the plot. The 66 plexiglass plates cover a total area of 0.952 m<sup>2</sup>, or 1.55% of the peripheral area to a height of 1.8 m. Extrapolating that the five *M. occidentalis* collected on the plexiglass plates represent 1.55% of the total number aerially dispersing within that area, we conclude that aerial dispersal of *M. occidentalis* involved several hundred females. Although this extrapolation may statistically seem of little value, Hoy et al. (1984) used the same type of extrapolation in a California almond orchard to estimate that the numbers of dispersing mites could be in the millions over the same time interval. Thus, the plot management scheme adopted appears to be useful in reducing rates of aerial dispersal.

TABLE 2. SUMMARY OF *M. OCCIDENTALIS* COLLECTED FROM AERIAL DISPERSAL PLATES. THE DATE LISTED IS THE DATE THE PLANTS WERE COLLECTED; HEIGHT REPRESENTS THE HEIGHT OF THE TOP OF THE PLATE ABOVE THE GROUND; AXIS IS THE GENERAL DIRECTION OF THE PLATE IN RELATION TO THE PLOTS; WIND DIRECTION IS THE PREVAILING WIND DIRECTION IN DEGREES AVERAGED OVER THE PREVIOUS SEVEN DAYS.

Date (Julian)	Number of <i>M. occidentalis</i>	Height (cm)	Axis	Wind Direction (°)
211	3	110	N	187°
260	1	54	N	97°
260	1	110	E	97°

Four living and two dead adult female *M. occidentalis* were found on the permethrin-treated trap crops and barrier rows over the course of the experiment. All represented single individuals found on different dates (days 176, 190, 197, 225, 232, 267). No *M. occidentalis* eggs were found on the barrier rows, suggesting that a population had failed to develop there despite the presence of prey. Spider mites had no difficulty dispersing from the infested center row to the outer barrier rows, and mean spider mites per leaf ranged from 0.2 to 19.4 per leaf, so sufficient prey was available to sustain *M. occidentalis* if they had dispersed there.

#### The CLIMEX Model

The upper portion of each graph shows 30 year average monthly temperatures and precipitation from the CLIMEX meteorological database (Figs. 4A, 4B). The bottom portion of each graph shows the population growth index for *M. occidentalis*. The line labeled "GI" indicates predicted population growth during the year. Population growth is maximized where  $GI = TI$ . Figures 4A and 4B indicate that *M. occidentalis* may not enter a winter diapause in much of Florida, and that it can indeed survive the drier and cooler spring, fall, and winter months. Both graphs indicate that *M. occidentalis* populations should decrease to zero in the summer months (July, August, September). The model predicts that populations start to crash earlier in Tampa (mid-June), than in Jacksonville (early July). This could be expected since Tampa has a higher average rainfall for the month of June. The model also predicts that *M. occidentalis* populations could establish earlier in the fall in Tampa (late September) than in Jacksonville (mid-October). This is because September is the wettest month of the year for Jacksonville, while July and August are the wettest months in Tampa. Since *M. occidentalis* does not have a summer estivation to carry it through the stressful months of July, August, and September, the Ecoclimatic Index for both cities is zero, indicating that *M. occidentalis* will not permanently establish in Florida.

#### DISCUSSION

Both the CLIMEX model and the field plot data suggest that *M. occidentalis* populations will not survive the summer months in Florida without reintroductions. The CLIMEX model indicates that *M. occidentalis* could establish in Tampa and Jacksonville during the drier fall, winter and spring months, but persistence in Gainesville is only suggested from the experimental data during April. Populations of both *M. occidentalis* and *T. urticae* were negatively impacted by high rainfall (Fig. 2). According to Sutherst & Maywald (1985), the three most important aspects of the climate in determining distribution and abundance of animals are temperature, moisture, and for some species, daylength. Field & Hoy (1986) showed that *M. occidentalis* larvae do not mature well at high relative humidities and that egg hatch is inhibited. Herne (1968) found that immersion of the European red mite, *Panonychus ulmi* (Koch), arrested feeding, oviposition, and molting activities. Klubertanz et al. (1990) suggested that wetted leaf canopy may temporarily retard spider mite population growth. Akinlosotu (1982) and Yaninek et al. (1987, 1996) found that in the absence of significant predators, weather was the greatest limiting factor in cassava green mite (CGM), *Mononychellus tanajoa* (Bondar), populations in Africa. CGM populations were highest during the dry season and were lowest during the wet season, when precipitation exceeds evaporation (Yaninek et al. 1987). What we observed in this experiment may be a combination of both direct mortality from the rainfall and population decline from the wetted canopy. Most of Florida's summer rains occur in the late afternoon and

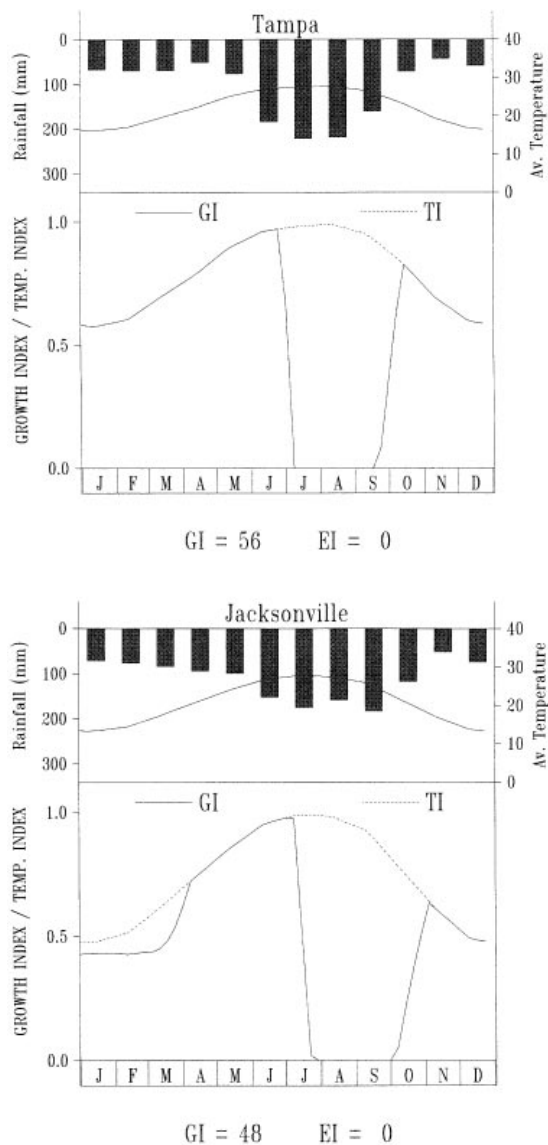


Fig. 4. A. Predicted population growth curves for *M. occidentalis* based on Tampa, Florida meteorological data from the CLIMEX model. B. Predicted population growth curves for *M. occidentalis* based on Jacksonville, Florida meteorological data from the CLIMEX model. Upper portion of graphs shows average monthly temperatures (°C, line) and average monthly rainfall (mm, bars). Bottom portion of graphs depicts Temperature Index (TI) and Growth Index (GI) of *M. occidentalis*. Population growth is maximized where GI=TI. An Ecoclimatic Index (EI) of 0 indicates climatic conditions are not favorable for permanent survival of *M. occidentalis*.



early evening hours and are followed by high nighttime relative humidities peaking at >95% between 3:00 and 6:00 am. A combination of rain and dew can keep the canopy wet for almost all of the evening and nighttime hours.

Results from this study indicate that the permethrin-treated barrier rows did provide an effective barrier to ambulatory dispersal of *M. occidentalis*, although some aerial dispersal did occur. While we recognize that this experimental design may not be optimal from some standpoints, it is very pragmatic for risk assessment studies which require small easily sampled and easily mitigated treatment plots. Although we detected low rates of aerial dispersal, our sampling method undoubtedly underestimated the incidence of aerial dispersal. However, all other evidence suggests that any transgenic *M. occidentalis* that do disperse will be unlikely to permanently establish and persist in Florida.

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DIAMONDBACK MOTH (LEPIDOPTERA: PLUTELLIDAE)  
INFESTATION AND PARASITISM BY *DIADEGMA INSULARE*  
(HYMENOPTERA: ICHNEUMONIDAE) IN COLLARDS AND  
ADJACENT CABBAGE FIELDS

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ABSTRACT

Two rows of collard greens (*Brassica oleracea* var. *acephala* L.) were planted between two cabbage fields in Bunnell, Flagler County, Florida in spring 1995. More larvae of the diamondback moth (DBM), *Plutella xylostella* (L.), were found on collard plants than on cabbage plants in the adjacent fields. The parasitism rate of DBM larvae collected from the collard plants reached 72% in early May and was higher than for larvae collected from the cabbage plants in adjacent fields. Parasitoids recovered from DBM larvae were mainly *Diadegma insulare* (Cresson). The damage to collard plants caused by DBM larvae was greater than on cabbage plants. At harvest, there was no significant difference in damage ratings of cabbage heads sampled near the middle of the field and damage to heads on rows nearest the collards. The results suggest that collard may have potential as a trap crop of DBM in cabbage fields, and that collard can play an important role in maintenance of the natural enemy, *D. insulare*.

Key Words: *Plutella xylostella*, *Conura side*, *Spilochalcis*, population regulation, *Brassica oleracea*

RESUMEN

Fueron plantadas dos hileras de acelga, *Brassica oleracea* var. *acephala*, entre dos campos de col en Bunnell, condado de Flagler, Florida, en la primavera de 1995. Fueron encontradas más larvas de *Plutella xylostella* (L.) en las acelgas que en las coles de los campos adyacentes. Las tasas de parasitismo de las larvas de *P. xylostella* en la acelga alcanzaron el 72% a principios de mayo y fueron más altas que en la col. Los parasitoides recuperados fueron principalmente *Diadegma insulare* (Cresson). El daño causado por *P. xylostella* fue mayor en las plantas de acelga. En el momento de la cosecha, no hubo diferencia significativa en el daño de las coles muestreadas junto a las acelgas o en el centro del campo. Los resultados sugieren que la acelga podría tener potencial como cultivo trampa para *P. xylostella* en campos de col y puede jugar un papel importante en el mantenimiento de *D. insularis*.

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The diamondback moth (DBM), *Plutella xylostella* (L.), is the most destructive pest of cabbage and other crucifers throughout the world. The annual cost for control of this pest is estimated to be U.S. \$1 billion (Talekar & Shelton 1993). This pest typically has been controlled with pesticides (Shelton et al. 1993a). The diamondback

moth, however, has become resistant to synthetic insecticides used against it in many countries (Shelton et al. 1993a, Talekar & Shelton 1993). In the USA, control failures have occurred in several states including Florida, Georgia, North Carolina, Texas, Wisconsin, and New York (Shelton et al. 1993b). Therefore, other control tactics, including biological control, cultural control and the use of pheromones (McLaughlin et al. 1994), should be integrated in the management strategy for this pest.

Cultural practices can be efficient and ecologically sound methods for control of DBM. Successful use of Indian mustard [*Brassica juncea* (L.) Czern] as a trap crop for management of DBM on cabbage has been recorded from India (Srinivasan & Krishna Moorthy 1992). Intercropping cabbage with garlic or tomato has been reported in Central America (Andrews et al. 1992), but substantial reduction of DBM infestation in cabbage has not been reported. In Hawaii, however, interplanting cabbage with tomato has shown significant reduction of larval density of DBM in cabbage (Bach & Tabashnik 1990). The objective of this study was to compare DBM densities, damage to cabbages, and larval parasitism on collard plants and cabbage plants in adjacent fields.

#### MATERIALS AND METHODS

##### Experimental Location

The cabbage fields used in the study were located in Bunnell, Flagler County, Florida. Cabbage seedlings (*Brassica oleracea* var. *capitata* L.) were planted into two adjacent fields 4 January (field B) and 20 January (field A), 1995, respectively. Two rows of collard seedlings (*Brassica oleracea* var. *acephala* L.) were planted between these two fields 27 January. Field B (5.26 ha) was on the north side of the collard rows, and field A (5.06 ha) was on the south side (Fig. 1). Cabbage and collard plants were planted in rows 0.76 m apart with 0.23 m plant spacing. The length of each row was 275 m.

##### Insect Sampling

DBM larvae (1st to 4th instars) on cabbage were sampled weekly beginning 17 January for field B and 9 February for field A; and the larvae and cocoons on collard plants were sampled beginning 13 March. The collards were sampled at 10 different sites, each 20 m apart along the rows. Six sites in a grid pattern were sampled in each cabbage field (Fig. 1). Three sites in a row were in each outer third (35 m from the edge) of the cabbage field, with 3 sites next to the collards and 3 sites at the opposite side of the field (away from the collards). The number of plants sampled at each site decreased as their size increased, from 65 cabbage plants the first wk to 13 the last wk of sampling and from 47 collard plants the first wk to 5 the last wk of sampling.

DBM larvae were brought into the laboratory and held for emergence of parasitoids and diamondback moths. If nothing emerged, the hosts were dissected (Day 1994) to examine parasitoids. The larvae were reared in 0.26-liter food cups (10 cm high × 5 cm diam) under laboratory conditions of 21°C, 50–60% RH, and 12:12 [L:D] photoperiod. A 5 cm diam hole was cut through the center of the cup's lid, and the hole was coated with Porex™ porous plastics (Porex Technologies, Fairburn, Georgia) for ventilation. Fresh collard leaves were supplied for food daily.

##### Cabbage Damage Rating

At harvest, 13 consecutive mature cabbage heads >15.2 cm diam at each site were individually rated using the rating scale developed by Greene et al. (1969) and modi-

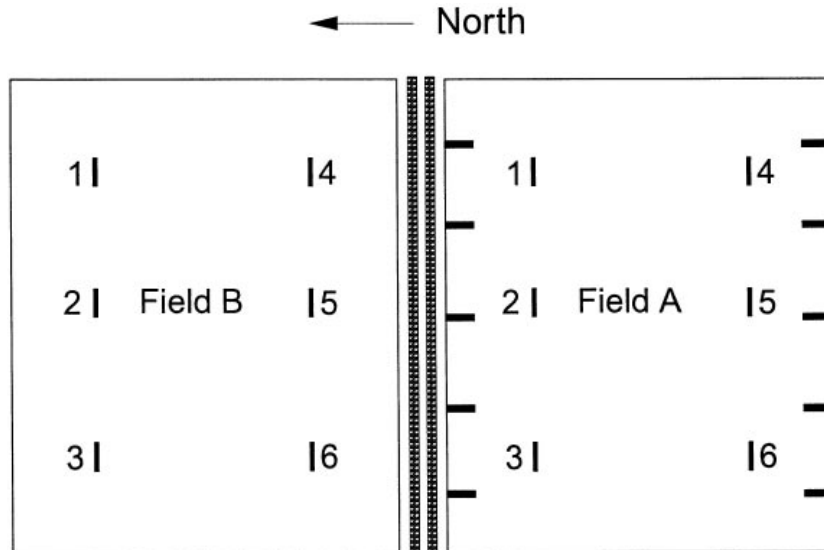


Fig. 1. Schematic of collard plantings and adjacent cabbage fields. Two vertical dotted lines between field A and B are the collard planting. Vertical bars in the cabbage fields indicate sampling sites for DBM immatures and cabbage head damage ratings. Horizontal bars in field A indicate cross-ratings of the first 12 rows of cabbage heads from edges of the field.

fied by Leibee et al. (1995). The ratings were: 1) no damage on head or 4 wrapper leaves; 2) no head damage but minor feeding damage on wrapper leaves; 3) no damage on head but obvious feeding damage on wrapper leaves; 4) very minor feeding damage on head, but no feeding through outer head leaves; 5) feeding damage through outer head leaves; and 6) severe damage to head and wrapper leaves. Leibee et al. (1995) categorized cabbage heads rated  $\leq 3$  marketable under normal market conditions. However, the growers with whom we were working considered only cabbage heads rated in categories 1 and 2 as acceptable to the market in spring 1995.

Besides rating cabbage at the permanent sample sites in each field, damage ratings also were made on cabbage at selected sites along the field edges. Five sampling sites, 50 m apart, were chosen along each edge of field A (Fig. 1); five cabbage heads were rated in each of the first 12 rows from the edge at each site. Unfortunately, this was not done for field B because the cabbage heads were harvested before we could collect data.

#### Statistical Analysis

The variation of DBM larval counts, the percentage of parasitism and cabbage ratings at the permanent sites between collard and cabbage plants in both fields were analyzed using general linear models procedure (GLM), and differences between the means were tested with least significant difference multiple range test (LSD; SAS Institute, 1990). The raw numbers were transformed by  $\log(n + 1)$  to meet the assumptions of GLM (Marks 1990) before performance of the analysis. Average damage

ratings of cabbage along edges of field A were analyzed with an independent student *t*-test for each of the 12 rows.

RESULTS

DBM Larval Abundance

Numbers of DBM larvae per collard plant were inconsequential until mid-March and then increased rapidly to a peak in late April (Fig. 2). Numbers of DBM cocoons per collard plant showed a trend similar to that observed for DBM larvae (Fig. 2).

Densities of DBM larvae on collard plants on each collection date were greater than densities on cabbage plants in fields A and B (Fig. 3). Mean numbers of DBM larvae per plant from 13 March to 10 April were significantly higher on collard plants than on cabbage plants in fields A and B (13 March,  $F = 4.12$ ;  $df = 2, 19$ ;  $P < 0.05$ ; 20 March,  $F = 7.98$ ;  $df = 2, 19$ ;  $P < 0.01$ ; 28 March,  $F = 13.75$ ;  $df = 2, 19$ ;  $P < 0.01$ ; April 3,  $F = 38.43$ ;  $df = 2, 19$ ;  $P < 0.01$ ; 10 April,  $F = 16.68$ ;  $df = 2, 19$ ;  $P < 0.01$ ), but no significant differences were shown between the two cabbage fields ( $P > 0.05$ ). These results suggest that the collards were more attractive than cabbage to gravid DBM females.

Parasitism

The parasitism rates of DBM larvae from collard showed an increase from 3.2% on 13 March to 72% on 1 May (Fig. 2). By contrast, parasitism rates of DBM larvae on cabbage remained very low throughout the season, even at harvest (Fig. 4). The per-

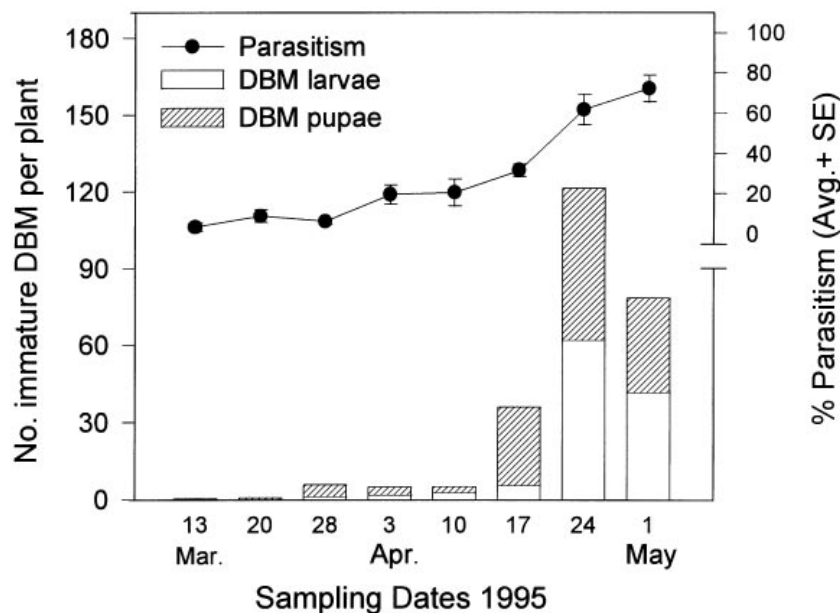


Fig. 2. Average numbers of diamondback moth larvae and pupae per collard plant and the larval parasitism (% ± SD) per site by *D. insulare*.

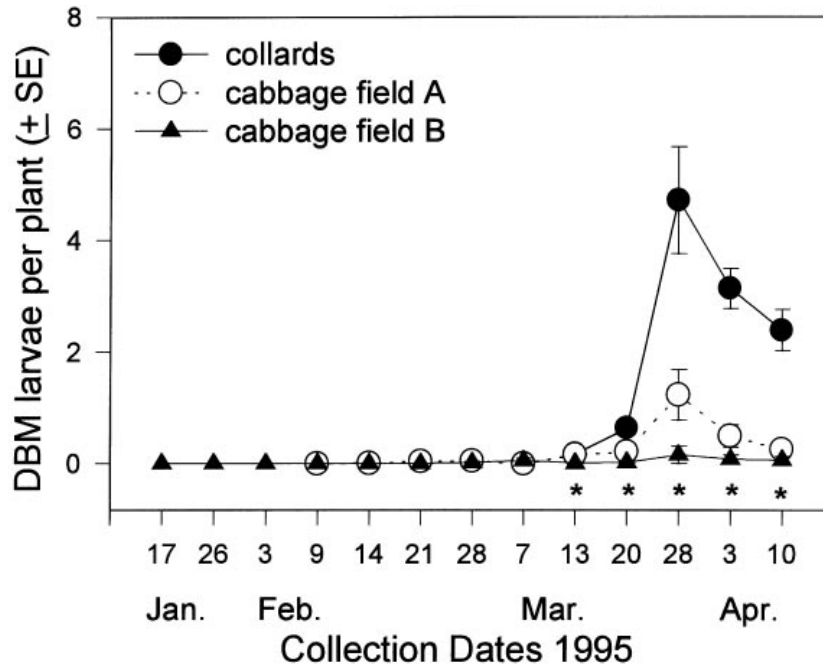


Fig. 3. Average numbers of diamondback moth larvae per collard plant and per cabbage plant from adjacent fields; \* shows that means are significantly different on the same sampling dates.

cent parasitism of DBM larvae on the collards from 4 and 10 April was significantly higher than on cabbage ( $F = 13.35$  and  $7.54$ , respectively;  $df = 2, 19$ ;  $P < 0.01$ ). The difference in DBM larval parasitism in fields A and B was not significant ( $P > 0.05$ ).

Of 1,812 parasitoids found, 1,683 were reared to adults and 129 were dissected at the larval, pupal or pharate adult stage. *D. insulare* was the most abundant parasitoid (99.5%), and the sex ratio was 1:1.1 ♀:♂. No obviously biased sex ratio was found from each collection throughout the season. Eight *Conura (Spilochalcis) side* (Walker) (Hymenoptera: Chalcididae) (0.5%) were reared from DBM cocoons collected in April.

The numbers of parasitoids collected and the densities of DBM larvae were not correlated ( $r = 0.3403$ ,  $df = 14$ ,  $P > 0.05$ ), but percent parasitism and the DBM larval densities were correlated ( $r = 0.7183$ ,  $df = 14$ ,  $P < 0.05$ ). There were significant correlations ( $r = 0.8876$  and  $0.9723$ , respectively;  $df = 14$ ;  $P < 0.01$ ) between the numbers of the DBM larvae collected at any particular week and the percent parasitism and the numbers of parasites collected 2 weeks later (i.e., 2-week-lag, Fig. 5).

After the field collections were finished, the collard plants (heavily damaged by feeding of DBM larvae) were brought into the laboratory, and the cocoons of DBM and *D. insulare* were collected and checked for parasitoids. From 607 cocoons collected, 284 parasitoids emerged (46.8%). The parasitoids included 225 *D. insulare* (79.3%), 39 *C. side* (13.7%) and 20 unidentified hymenopterous parasitoids (7%). The sex ratio of *D. insulare* was 1:1.5 (♀:♂).

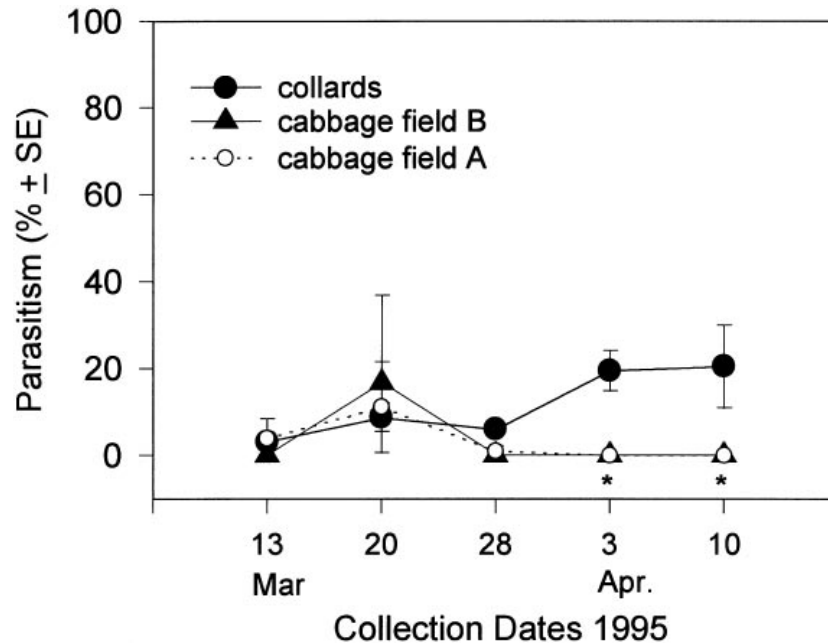


Fig. 4. Percent parasitism of diamondback moth larvae by *D. insulare* per site on collard and cabbage plants in adjacent fields; \* shows that means are significantly different on the same sampling dates.

#### Cabbage Damage Rating

Percentage of marketable cabbage heads in rows 1-12 did not show significant differences between the north and south sides ( $P > 0.05$ ). The cabbage damage ratings for the plots from inner 1/3 of fields A ( $1.36 \pm 0.55$ ) and B ( $1.31 \pm 0.60$ ) were not significantly different ( $F = 0.3088$ ;  $df = 3, 152$ ;  $P > 0.05$ ) from the outer 1/3 of these fields (farthest away from the collards, Fig. 1) of field A ( $1.41 \pm 0.62$ ) and B ( $1.26 \pm 0.40$ ). There also was no significant difference in the percentage of marketable cabbage heads among those sampling locations ( $F = 1.2381$ ;  $df = 3, 8$ ;  $P > 0.05$ ). This suggests that DBM populations did not spread from the collards to the adjacent cabbage fields even though the DBM population reached very high levels in the collards. Leaves of the collard plants were observed to have much heavier damage by DBM larvae than cabbages throughout the season.

#### DISCUSSION

Compared with the cabbage plants in the adjacent fields, collard plants had greater DBM larval infestation and suffered greater damage. Therefore, collard may be evaluated as a trap crop in cabbage fields for control of DBM. Detailed interplanting plans may be needed for large area trial as the use of Indian mustard in cabbage fields (Srinivasan & Krishna Moorthy 1992). Planting collards earlier than cabbage may help to attract early arrivals of DBM. Planting collards over a larger area in and



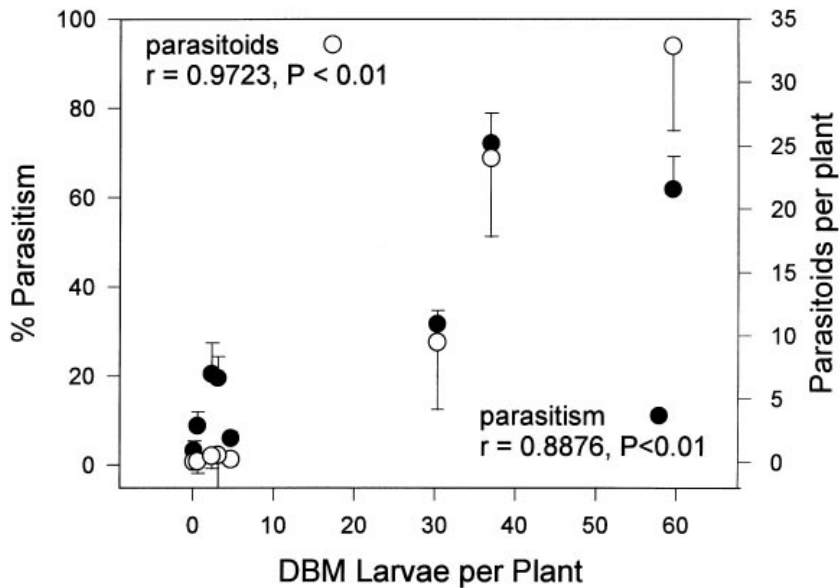


Fig. 5. Correlation showing the relationship between % parasitism and the numbers of parasitoids per collard plant and the numbers of DBM larvae per plant. The parasites were collected 2 weeks later than were the DBM larvae (i.e., 2-week-lag).

around cabbage fields may offer growers a significant level of protection of their cabbage crop from attack by DBM.

In the study of Harcourt (1957), collards were shown to have greater numbers of DBM larvae than six other cultivated crucifers (including cabbage), which agrees with our results.

It is not clear why DBM is more attracted to collards than cabbage. It is reported that DBM is attracted to crucifers that contain chemical stimulants (Talekar & Shelton 1993) for feeding (e.g. glucosides) and oviposition (e.g., sulfur-containing glucosinolates). Collards may contain higher levels of those volatile chemicals than does cabbage.

*D. insulare* has been recorded from Southern Canada to Venezuela and west to Hawaii (Fitton & Walker 1992) and is a major parasitoid of DBM in north America (Harcourt 1960, Idris & Grafius 1993, Lasota & Kok 1986). High parasitism in collards and the significant correlations shown in our study between the 2-week-lagged DBM larval abundance and parasitism by *D. insulare* suggest that this species was responsible for regulating DBM populations in the collards. When the parasitism reached a certain level (64%, April 24), the population of DBM in collards started to decrease (Fig. 2). However, *D. insulare* did not show the same relationship with DBM in the cabbage fields, possibly because of the low densities of the host.

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This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or the recommendation for its use by USDA.

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A NEW WORLD SPECIES OF *CYMOPHYES* AND A NEW  
SPECIES OF *XYONYSIUS* FROM THE TURKS AND CAICOS  
ISLANDS (HEMIPTERA: LYGAEIDAE)

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ABSTRACT

*Cymophyes nesocoris* **New Species** and *Xyonysius acticola* **New Species** are described from the Turks & Caicos Islands, British West Indies. Species of *Cymophyes* have previously been known to occur only in the Eastern Hemisphere. The immature stages are described and the hosts and habitats discussed.

RESUMEN

*Cymophyes nesocoris* **Nueva Especie** y *Xyonysius acticola* **Nueva Especie** son descritas de las islas Turks y Caicos, Antillas Britámicas. Anteriormente, las especies de *Cymophyes* eran sólo conocidas del Hemisferio Oriental. Son descritos los estados inmaduros y discutidos los hospedantes y habitats.

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During the course of our work on the lygaeid fauna of the West Indies two unusual new species have been collected on the Turks and Caicos Islands. The most striking of these is an undescribed species of *Cymophyes* Fieber, a genus which has not been known previously to occur in the Western Hemisphere.

We also recognize a new species of the orsilline genus *Xyonysius* Ashlock & Lattin whose closest relative appears to be an endemic species from the Galapagos Islands. All measurements are in millimeters.

*Cymophyes nesocoris* Baranowski and Slater, **New Species**

(Fig. 1)

**DESCRIPTION.** General coloration stramineous, heavily punctate. Conspicuously differentiated brown to black punctures as follows: on midline of head, antenniferous tubercles, first, second, basal half of third antennal segments, midline and lateral margins of pronotum, a single row on either side of midline of scutellum, a few irregularly spaced on corium, forming a longitudinal vitta through the middle of pro-, meso-, and metapleuron, mesally on meso- and metasternum, all of femora and tibiae dark brown; punctures on rest of body stramineous, concolorous with body surface. Abdominal terga with a pair of dark brown vittae, composed of dark brown punctures, merging mesally on last two segments. Wings not reaching end of abdomen.

Head elongate, strongly tapering anteriorly, apex of tylus slightly exceeding distal end of first antennal segment. Length head 0.70, width 0.60, interocular space 0.38. Pronotum slightly narrowing from posterior to anterior margin, lateral margins very slightly sinuate, anterior margin concave, posterior margin straight. Length pronotum 0.82, width across anterior margin 0.52, width across posterior margin 0.90. Scutellum slightly elevated along midline, but lacking a definite carina. Length scutellum 0.40, width 0.42. Length claval commissure 0.36. Distance along midline from apex clavus to apex corium 0.76. Distance along midline from apex corium to apex wing membrane 1.06. Forefemora strongly incrassate, armed below with a series of major and minor spines with the apices darkened. Labium extending between forecoxae. Length labial segments I 0.29, II 0.29, III 0.14, IV 0.23. Antennae thick, all segments with short hairs, segment IV impunctate, segment I enlarged distally. Length antennal segments I 0.23, II 0.40, III 0.33, IV 0.38. Total body length 4.70.

**TYPES.** Holotype. ♂ **Turks and Caicos Isl., B.W.I., North Caicos Island:** Horse Stable Beach Rd., 22-X-1993 (on *Sporobolus domingensis*), R. M. & H. V. Baranowski. In U.S. National Museum of Natural History. Paratypes. 133♂, 189♀, same data as holotype; 16♂, 24♀, same except 26-XI-1994; 3♂, 5♀, same except Mudhole Pond; 3♂, 2♀, same except 0.5 mi S. Horse Stable Beach, 26-VI-1993; 108♂, 188♀, same except 27-VI-1993. **Middle Caicos Island:** 21♂, 19♀, Julia Williams Point, 24-X-1993, (on *Sporobolus domingensis*), R. M. & H. V. Baranowski; **Providenciales Island:** 4♂, 7♀, 0.5 mi N. Downtown, 19-X-1993, (on *Sporobolus domingensis*), R. M. & H. V. Baranowski; 124♂, 136♀, Leeward, 19-X-1993 (on *Sporobolus domingensis*), R. M. & H. V. Baranowski; 20♂, 20♀, Leeward Hwy., Pole #A139, 20-X-1995, (on *Sporobolus domingensis*), R. M. & H. V. Baranowski; 132♂, 186♀, 0.5 mi S. Downtown, 20-X-1993, (on *Sporobolus domingensis*), R. M. & H. V. Baranowski; 4♂, 5♀, same except 23-XI-1994. In U.S. National Museum of Natural History, American Museum of Natural History, Natural History Museum (England), Florida State Collection of Arthropods, R. M. Baranowski and J. A. Slater collections.

**ETYMOLOGY.** Referring to the island distribution.

This species will key to *C. ochroleuca* Fieber in Seidenstucker (1953) (see English translation in Slater 1955), but it is not actually closely related. *Cymophyes ochroleuca* is the most elongate of the species in the nominal subgenus but is considerably less elongate than is *C. nesocoris*. The latter has a body at least five and one-fourth times the maximum width. *C. ochroleuca* has a maximum length/width ratio not greater than four and one-fourth times as long as wide. None of the described species of *Cymophyes* have conspicuous black punctures on the antennal segments. The genus *Stenophyella* does have punctate antennal segments but also has a conspicuously bifid apex on the abdomen which is not the case with the new species described here. *Stenophyella* has been thought to be confined to Australia but we have examined specimens from Thailand, Macao, Vietnam, Papua New Guinea and New Caledonia.

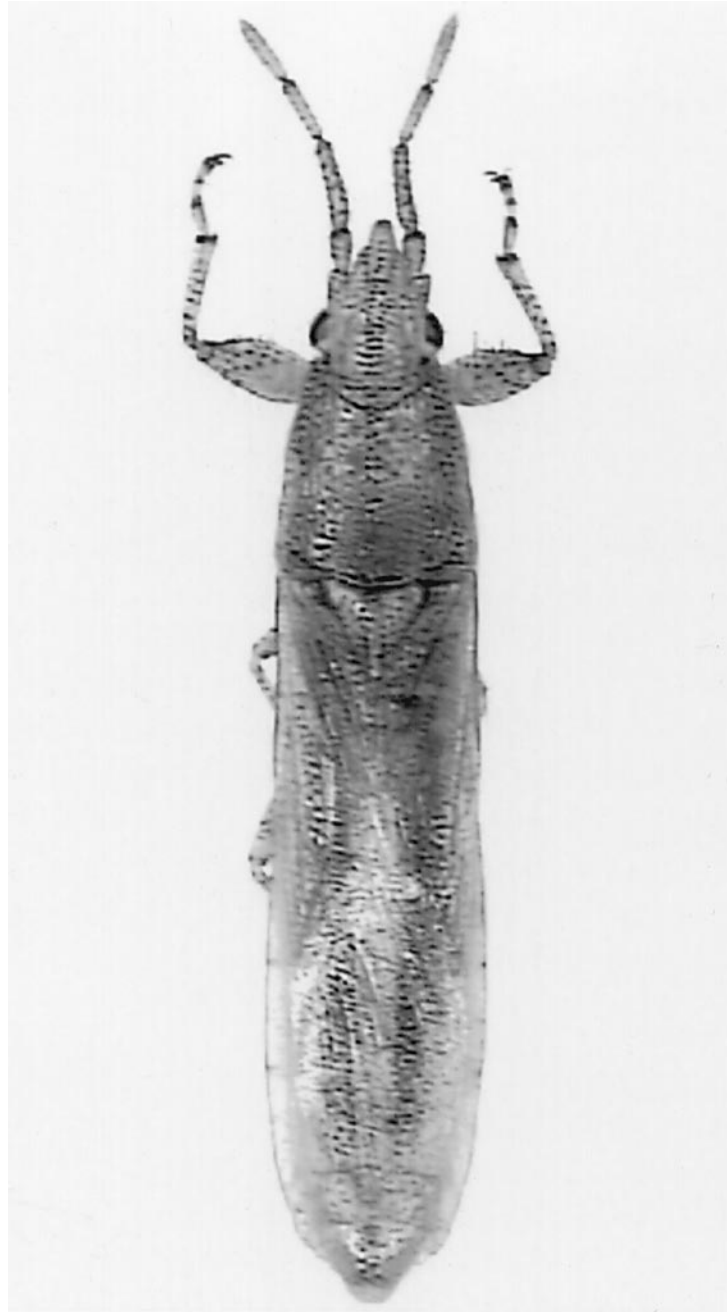


Fig. 1. *Cymophyes nesocoris* Baranowski and Slater, **New Species**, dorsal view.

Lindberg (1958) recognized the similarity of *Cymophyes* and *Stenophyella* when he described an elongate species from the Cape Verde Islands as *Stenophyella africana*. Slater (1966) noted that Lindberg's species lacked a bifid apex on the abdomen and transferred *S. africana* to *Cymophyes*. Linnavuori (1978) erected the subgenus *Afrophyella* in the genus *Cymophyes* for *C. africana* because of its extremely elongate body.

*Cymophyes (Afrophyella) africana* is a very elongate species. It is, in fact, much more elongate than is *C. nesocoris*, the length/width ratio being at least 7.5 and sometimes over 8, whereas in *C. nesocoris* the ratio is less than 5.5. It also lacks the black antennal punctures and is an overall very pale species throughout with at most a faint trace of darkened punctures as a faint line along the pleural surfaces. In addition to the type locality Linnavuori (1978) reported *C. africana* from the Sudan, Ethiopia and Pakistan. We have examined Ethiopian and Pakistan specimens and agree that they appear to be conspecific.

We treat *C. nesocoris* in the nominal subgenus *Cymophyes* despite its more elongate body and black antennal puncture.

DISTRIBUTION. *Cymophyes nesocoris* was collected on the islands of Providenciales, Middle Caicos and North Caicos. It was not found on Grand Turk nor on the islands of Andros and Long Island in the Bahamas even though the host plant was present. Subsequent to the completion of this manuscript, Dr. Horatio Grillo of the Universidad Central de Las Villas, Santa Clara, Cuba, brought to the attention of the junior author a question he had first raised as early as 1978 concerning the possibility of an insect similar to *Cymophyes* occurring on Cuba. Dr. Grillo has been kind enough to send pictures of specimens from Cuba and also to allow us to include the information in this paper. His photographs clearly indicate that Cuban material is conspecific with *Cymophyes nesocoris*. Thus, not only is the species also present in the Greater Antilles, but if it is an introduced species, it was established sometime before 1978.

The discovery of a species of this otherwise Eastern Hemisphere genus in the West Indies, more specifically the Bahama Archipelago, raises questions as to whether we are dealing with an introduction or an endemic but previously overlooked taxon. The most probable scenario seems to us to consider *C. nesocoris* to be an introduced species from an as yet unknown place in the Eastern Hemisphere. Much of the West African lygaeid fauna is still poorly known and seems a likely area for investigation. Given the prevailing east to west trade winds at the latitude of the Turks and Caicos Islands, the possibility of the species having reached the islands by aerial transport seems higher than by introduction in commercial or recreational ships or planes. On the other hand it must be recognized that *C. nesocoris* is not really extremely closely related to any of the known species of *Cymophyes* and does have similarities to species of *Stenophyella*. One must thus take into account the former presence of a member of this complex in the past in the Western Hemisphere. Sailer & Carvalho (1957) described a Miocene fossil species from the Mojave desert in California as *Procymophyes lithax*.

Thus we face the fascinating question of whether we are dealing with a previously unknown species from somewhere in the Eastern Hemisphere or a hitherto uncollected vicariant species, native to the Western Hemisphere.

#### BIOLOGY OF *C. NESOCORIS*

*Cymophyes nesocoris* was collected only on *Sporobolus domingensis* (Trin.) Kunth. (Poaceae), a common roadside grass in the Greater Antilles, the Bahama Archipelago and south Florida. All stages were found in the seedheads during the periods collected. Eggs are deposited, typically singly, between the seed and sheath. Nymphs and adults were observed feeding on the seeds. Other species of grasses were swept at several sites where *S. domingensis* was present without collecting *C. nesocoris*.

DESCRIPTION OF *C. NESOCORIS* NYMPHS AND EGG

## Fifth instar (in alcohol)

Elongate, slender, stramineous in color. Head and body impunctate. Antennae, femora and tibiae with brown punctation. Pro- meso- and metapleuron with a light brown longitudinal vitta. Wing pads, lateral margins of pronotum and midline of scutellum pronotum and head brown. Legs light brown, eyes red. Each abdominal tergite with a pair of small brown spots. Length head 0.68, width 0.63, interocular space 0.43. Length pronotum 0.63, width 0.90. Length wing pads 1.33. Length abdomen 3.0. Length labial segments I 0.28, II 0.24, III 0.16, IV 0.22. Length antennal segments I 0.20, II 0.38, III 0.32, IV 0.38. Total body length 4.50.

## Fourth instar (in alcohol)

Shape and color similar to preceding instar. Length head 0.60, width 0.48, interocular space 0.34. Length pronotum 0.40, width 0.34. Length wing pads 0.62. Length abdomen 1.80. Length labial segments I 0.16, II 0.20, III 0.16, IV 0.16. Length antennal segments I 0.14, II 0.26, III 0.22, IV 0.32. Total body length 3.10.

## Third instar (in alcohol)

Shape and color similar to preceding instar. Length head 0.40, width 0.42, interocular space 0.30. Length pronotum 0.26, width 0.52. Length wing pads 0.22. Length abdomen 1.40. Length labial segments I 0.16, II 0.24, III 0.12, IV 0.16. Length antennal segments I 0.10, II 0.18, III 0.18, IV 0.28. Total body length 2.36.

## Second instar (in alcohol)

Shape and color similar to preceding instar. Length head 0.38, width 0.32, interocular space 0.22. Length pronotum 0.18, width 0.40. Length abdomen 1.0. Length labial segments I 0.12, II 0.16, III 0.10, IV 0.14. Length antennal segments I 0.06, II 0.12, III 0.12, IV 0.24. Total body length 1.70.

## First instar (in alcohol)

Shape and color similar to preceding instar. Length head 0.28, width 0.28, interocular space 0.24. Length pronotum 0.12, width 0.30. Length abdomen 0.56. Length labial segments I 0.10, II 0.14, III 0.06, IV 0.14. Length antennal segments I 0.06, II 0.10, III 0.10, IV 0.22. Total Body length 1.10.

## Egg (in alcohol)

Elongate, tapering to both ends, operculum flat with 6-10 micropylar projections, opposite end rounded. Length 0.74, width at middle 0.26, operculum 0.10.

*Xyonysius acticola* Baranowski and Slater **New Species**

(Fig. 2)

DESCRIPTION. General coloration brown to griseus; head brown with a pale midline vitta extending from base anteriorly to approximately middle of eyes, a black



vitta on either side of midline extending anteriorly around ocelli to anterior eye margin; antennal tubercles marked with black laterally; ventral surface of head pale with a short black vitta on either side of labium; pronotum brown, median longitudinal carina of posterior pronotal lobe and humeri pale. Scutellum with a pale vitta extending from apex to midpoint. Hemelytra mottled brown; membrane with faint brownish markings. Upper half of pleuron brown, lower half yellowish, acetabula white. Femora brownish with proximal one-third yellow, tibiae and tarsi yellowish. Distal half of first antennal segment, all of fourth segment brown; proximal half of first, all of second and third yellowish.

Head nondeclivent, impunctate, tylus almost reaching distal end of first antennal segment. Length head 1.0, width 1.0, interocular space 0.60. Pronotum uniformly punctate with a faint medial longitudinal carina; anterior pronotal lobe with a transverse impression interrupted by the median longitudinal carina; lateral margins slightly sinuate, posterior margin slightly concave. Length pronotum 1.0, width 1.6. Scutellum punctate with three raised ridges, one extending from the base to the midpoint, the other two extending from the lateral margins of the base to the midpoint. Length scutellum 0.70, width 0.94. Length claval commissure 0.64. Midline distance apex clavus-apex corium 1.04. Midline distance apex corium-apex membrane 0.96. Length labial segments I 0.80, II 0.80, III 0.76, IV 0.40. First and fourth antennal segments enlarged, second and third slender. Length antennal segments I 0.36, II 0.78, III 0.66, IV 0.50. Total body length 5.25.

TYPES. Holotype. ♂ **North Caicos Isl.**, Horse Stable Beach, 23-X-93, on *Iva imbricata*, (R. M. & H. V. Baranowski). In U.S. National Museum of Natural History (NMNH). Paratypes. 54♂ 28♀, same data as holotype; 1♂, SAME except 26-XI-1994; 7♂ 14♀, Whitby 27-XI-94, on *Iva imbricata*, (R. M. & H. V. Baranowski). **Providenciales Isl.** 1♂, Grace Bay, 18-X-1993 (R. M. & H. V. Baranowski). In U.S. National Museum of Natural History, American Museum of Natural History, Natural History Museum, (England), Florida State Collection of Arthropods, R. M. Baranowski and J. A. Slater collections.

ETYMOLOGY. Referring to the beach habitat of the host plant.

*Xyonysius acticola* is readily distinguishable from the other West Indian species of *Xyonysius* by virtue of the elongate tylus and the relatively short fourth antennal segment. In *X. acticola* the length of the head measured along the midline from the level of the anterior margin of the eyes to the apex of the tylus is subequal to, or greater than, the length of antennal segment four. In both *X. californicus* and *X. basalis*, not only is the tylus less acuminate, but the fourth antennal segment is relatively much longer, more than one and one-half times the distance from the front margin of the eye to the apex of the tylus (1.66 is the lowest ratio in a series measured). The fourth antennal segment is also slightly shorter than segment three in *X. acticola*, but much longer than segment three in *X. californicus* and *X. basalis*.

*Xyonysius acticola* typically has a complete dark brown annulus on the distal half of the first antennal segment. Some specimens of *X. californicus* also have this complete annulus, but most specimens have only irregular dark markings rather than a complete distal annulus.

Actually *X. acticola* more closely resembles *X. naso* (Van Duzee) which is endemic (but widespread) on the Galapagos Islands. Like *X. acticola*, *X. naso* has the distance from the anterior margin of the eye subequal to the length of the fourth antennal segment. Both thus have noticeably more elongate acuminate heads than do other species of *Xyonysius*.

*Xyonysius naso* is readily separated from *X. acticola* by its much longer labium which extends posteriorly onto abdominal sternum three. In *X. acticola* the labium



Fig. 2. *Xyonysius acticola* Baranowski and Slater, **New Species**, dorsal view.

reaches between the metacoxae but not onto the abdominal sternum. This is reflected in the relatively much longer third labial segment in *X. naso* where labial segment three is slightly longer than segment two whereas in *X. acticola* it is shorter.

*Xyonysius acticola* is a relatively dark, often griseous appearing species with at least indications of four pale calloused patches across the middle of the pronotum and the calli cicatrices are never completely black. In the specimens of *X. naso* that we have examined the color is pale yellow (from Fernandina and Santa Cruz Islands) without any indication of pale calloused pronotal areas and with completely black pronotal cicatrices. Ashlock (1972) notes however that *X. naso* is quite variable in color (not geographically correlated incidentally) so that these color differences, although striking may not be definitive.

One of the most striking differences between these two long headed species is the shape of the bucculae. In *X. naso* the bucculae are very broad anteriorly, but narrow quickly and reach posteriorly only to the level of the anterior end of the antenniferous tubercles. In *X. acticola*, by contrast the bucculae are relatively low anteriorly but slope gradually and extend much further posteriorly to terminate at about the level of the anterior margin of the compound eyes.

It is interesting that both of these elongate headed species appear to be restricted in their use of host plants. Ashlock (1972) reported that *X. naso* was found breeding only on species of the endemic composite *Scalesia* and, as noted below, *X. acticola* is also restricted to a species of composite. This is in contrast to those mainland species of the genus for which biological data is available and which feed on a wide variety of plants.

#### BIOLOGY OF *X. ACTICOLA*

Adults and nymphs of *X. acticola* were found in the seed heads of *Iva imbricata* Walt. (Asteraceae). According to Correll and Correll (1982) this plant is found in the southeastern United States, the Bahamas and Cuba. Eggs, frequently more than one, are deposited between the seed and sheath. Adults and nymphs appear to feed only on the seeds. This plant was found only in the sand dune areas of the islands, a habitat similar to that of sea oats, *Uniola paniculata* L.

#### DESCRIPTION OF *X. ACTICOLA* NYMPHS AND EGG

##### Fifth instar (in alcohol)

Elongate, oval. Head, thorax, including wing pads a reticulated cream and brown with a few longitudinal brown irregular vittae. Abdomen a reticulated pink and cream, scent gland sclerites dark brown. Antennal segment I dark brown with distal tip cream, segments II and III yellow to tan, segment IV brown, segments I and IV slightly enlarged, segments II and III uniformly slender. Femora dark brown with proximal one third and distal tip cream; tibiae cream with distal one third brown; tarsi brown. Length head 1.10, width 1.0, interocular space 0.62. Length pronotum 0.62, width 1.60. Length wing pads 1.48. Length abdomen 2.55. Length labial segments I 0.70, II 0.70, III 0.72, IV 0.52. Length antennal segments I 0.28, II 0.52, III 0.46, IV 0.52. Total body length 5.22.

##### Fourth instar (in alcohol)

Similar in shape and color to fifth instar. Length head 0.70, width 0.80, interocular space 0.54. Length pronotum 0.38, width 1.10. Length wing pads 0.50. Length abdo-

men 1.84. Length labial segments I 0.44, II 0.54, III 0.44, IV 0.38. Length antennal segments I 0.20, II 0.32, III 0.30, IV 0.38. Total body length 3.25.

Third instar (in alcohol)

Similar in shape and color to preceding instars. Length head 0.60, width 0.60, interocular space 0.40. Length pronotum 0.26, width 0.76. Length wing pads 0.20. Length abdomen 1.40. Length labial segments I 0.38, II 0.46, III 0.44, IV 0.36. Length antennal segments I 0.12, II 0.20, III 0.18, IV 0.26. Total body length 2.55.

Second instar (in alcohol)

Similar in shape and color to preceding instars except head straw-colored with two irregular, longitudinal, tan, vittae on each side of midline. Thorax and abdomen reticulated cream and pink; thorax with one irregular, longitudinal, tan vitta on each side of midline. Length head 0.40, width 0.40, interocular space 0.30. Length pronotum 0.12, width 0.48. Length abdomen 0.78. Length labial segments I 0.30, II 0.36, III 0.30, IV 0.28. Length antennal segments I 0.10, II 0.12, III 0.14, IV 0.22. Total body length 1.46.

First instar (in alcohol)

Shape more elongate than preceding instars. Head and thorax brown. Abdomen similar to second instar. Legs colored as in preceding instar, but paler. Antennae light brown. Length head 0.38, width 0.30, interocular space 0.20. Length pronotum 0.14, width 0.30. Length abdomen 0.60. Length labial segments I 0.20, II 0.24, III 0.24, IV 0.24. Length antennal segments I 0.08, II 0.10, III 0.10, IV 0.20. Total body length 1.22.

Egg (in alcohol)

Elongate, straw-colored; length 1.1, width 0.3. Operculum 0.09 in diameter with 8-12 stalked, knobbed micropyles. Opercular end flattened, opposite end rounded.

The genus *Xyonysius* is confined to the Western Hemisphere. Previously nine species were recognized ranging from Chile and the Galapagos north to southern Canada (Slater and Baranowski 1990). Three species, including *X. acticola* are now recognized from the West Indies.

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DEGREE-DAY ACCUMULATIONS AND SEASONAL DURATION  
OF THE PRE-IMAGINAL STAGES OF THE MEXICAN FRUIT  
FLY (DIPTERA: TEPHRITIDAE)

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ABSTRACT

Degree-day accumulations and puparial duration of the Mexican fruit fly, *Anastrepha ludens* (Loew), in the field was found to fit closely with a degree-day accumulation model developed by Leyva-Vazquez (1988) with laboratory data. Larval development time was more variable, however, and did not agree well with the laboratory based degree-day model. This may have been caused by a tendency of the larvae to remain in the fruit beyond the necessary development time and for subsequent egression to be spread over a period of weeks. Duration of the pre-imaginal stages is strongly a function of season. The puparial stage may be prolonged up to three months in the winter or be as brief as three weeks in the summer. There was no evidence of a winter diapause.

Key Words: Degree-days, population model, citrus pest, diapause, *Anastrepha ludens*

RESUMEN

Se encontró que las acumulaciones de grados-días y la duración del estado pupal en el campo de la mosca mexicana de las frutas, *Anastrepha ludens* (Loew), se ajusta-

ban a un modelo de acumulación de grados-días desarrollado por Leyva-Vázquez (1988) a partir de datos de laboratorio. El tiempo de desarrollo larval fue más variable y no se ajustó bien al modelo. Esto pareció deberse a la tendencia de las larvas a permanecer en el fruto más allá del tiempo de desarrollo necesario, y a que su salida del fruto ocurre durante un período de semanas. La duración de los estados preimaginales está fuertemente en función de la estación. El estado pupal podría prolongarse hasta tres meses en el invierno, o ser tan breve como de tres semanas en el verano. No hubo evidencia de diapausa de invierno.

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Pre-imaginal development in the Mexican fruit fly, *Anastrepha ludens* (Loew), has been studied extensively under laboratory conditions (Darby & Kapp 1933, Baker 1944, Baker et al. 1944, Flitters & Messenger 1965, Celedonio-Hurtado et al. 1988). Flitter & Messenger (1965) state that development time for this species, egg to adult, ranges from 40-90 days under "normal" conditions.

Specific knowledge of pest phenology is an essential ingredient of effective pest management. Models based on population dynamics and the environmental parameters which drive them, almost invariably include the effect of temperature on development time. For example, the appearance of temperate tephritid pests, notably the apple maggot, *Rhagoletis pomonella* (Walsh), and the cherry fruit fly, *Rhagoletis indifferens* Curran, vary greatly from year to year but can be predicted by the standard degree-day method. Suppression operations are planned accordingly (Aliniazev 1976, Laing & Heraty 1984). The potential of a degree-day model for predicting outbreaks of the Mexican fruit fly, an intermittent but serious pest of citrus along the southern border of the United States, has long been recognized. The efforts to develop data for such a model are detailed in the present article and the efficiency of a degree-day based model of development time is assessed.

Leyva-Vazquez (1988) was the first to determine the degree-day accumulations for development time for each pre-imaginal stage under laboratory conditions. He reported  $316 \pm 10$  degree-days for the puparial stage and  $291 \pm 57$  combined degree-days for the egg and three larval instars. Using linear regression applied to the same data, the lower threshold of development was estimated to be at  $9.4^{\circ}\text{C}$ .

The purpose of the present investigation was to validate the degree-day calculations of Leyva-Vazquez (1988) obtained from laboratory experiments by determination of the duration and degree-day accumulations of the pre-imaginal stages under field conditions.

#### MATERIALS AND METHODS

All insects used in these experiments were from laboratory cultures maintained at the USDA facility in Weslaco, Texas, using the rearing methods described by Spishakoff & Hernandez-Davila (1968).

Duration of the larval stage was determined by placing infested grapefruit in an outdoor screened enclosure located in the center of a grove of citrus at the Weslaco site. For the purposes of this experiment, the duration of the larval stage was measured from the day of oviposition until the day the larvae egressed the fruit. At 2-week intervals, three fresh grapefruits were placed in a laboratory cage containing 15-d-old adult Mexican fruit flies and exposed to oviposition for a period of 4 hours. At the end of this exposure period each grapefruit was placed separately in 5-liter plastic tubs containing 10 cm of clean sand. The sides and bottoms of the tubs were punctured to

allow drainage. Two of the tubs were then placed in the outdoor enclosure, partly buried in the soil so that the level of the sand was at ground level. The third grapefruit was held in the laboratory at 25°C as a control. Beginning after 2 weeks, the minimum time for egg hatch and larval development, the sand in the tubs was sifted daily, except on weekends, to detect the presence of egressed larvae (larvae found on Monday were pooled and scored as if found on Saturday). The fruit was left in the tub until 2 weeks after the last larva had egressed. A recording hygrothermograph was maintained in the enclosure to provide ambient temperature data. This experiment began in July 1994 and continued through December 1995.

Duration of the puparial stage was determined by sprinkling 100 10-d-old larvae into each of five 5-liter capacity plastic tubs containing clean sand to a depth of 10 cm. Before placing the larvae, a small amount of water was sprinkled on the sand and holes poked in the surface with a narrow rod. The larvae were allowed to inter themselves in the sand, a process which normally required less than 10 minutes. Four of the tubs were then transported to the field and placed outdoors. The experiment was conducted from May 1992 to April 1993 at two sites in the state of Nuevo Leon, Mexico, an area in which the Mexican fruit fly is indigenous. One of the sites was a citrus orchard located near the town of General Teran. The other was a grove of wild citrus, *Sargentia greggi* Wats., in a mountain canyon 15 km west of the town of Linares. The experiment was also replicated at the Weslaco site between June 1993 and June 1994, again in the screened enclosure. Details of the environment at these locations and data on seasonal survival rates of the immature stages of the Mexican fruit fly have been described in a separate study (Thomas 1995). Briefly, freezing temperatures are rare in this region and during this study occurred on only one winter night when the temperatures reached -1°C. The winters and springs are typically dry with most rainfall in the summer months.

After two weeks of exposure a pyramid-shaped emergence cone, 60 cm<sup>2</sup> at the base, was placed over each of the individual tubs. Emerged adults accumulated in an inverted glass jar on the top of the cone. These cones were checked daily throughout the study, except on weekends. A recording hygrothermograph was maintained at each site to provide ambient temperature data.

Degree-days (°D) were calculated using the standard weather bureau formula, also known as the Means Method (Pruess 1983, Fry 1983),

$$[\text{Max} + \text{Min}/2] - \text{base.}$$

This formula was used by Leyva-Vazquez (1988) for the Mexican fruit fly and has been used successfully for other tephritid pests as well (Aliniaze 1976, Reissig et al, 1979). All temperature values were rounded to the nearest °C including the base, for which a value of 9°C was used. For statistical analysis, the correlations between degree-days and development time and day length and development time, were calculated using least squares regression (Sokal & Rohlf 1973). In the regression equation, day length was represented as the difference, in days, between the oviposition date and the summer solstice.

## RESULTS AND DISCUSSION

Laboratory studies have shown that temperature is a dominant factor determining larval development time. Flitters & Messenger (1965) reported 11-12 days larval development time at constant 27°C but were able to extend the larval stage to 125 days using a 12° ± 10°C temperature regime. In the present field study over the course of the year, the duration of the larval stage in grapefruit was found to range from as



few as 19 days in May to as many as 69 days for an oviposition in mid-November (Table 1). Although this result would seem to be in accord with the expected effect of seasonally prevailing temperatures, temperature alone may not have been the most dominant factor. There was typically a 1-2 week lag between the first and last larval egress in each test although presumably these larva were exposed to at least similar temperatures. In one test, with an oviposition date in mid-February, there was a 19 day spread between the first and last larval egress. Even in the controls, infested fruit maintained at constant temperature (24°C) in the laboratory, mean larval duration was 23.1 to 37.3 days, with an overall range from 19 to 54 days. It is noteworthy that some larvae in May, a warm month, did not egress until 29 days post-oviposition, while in November, a cool month, the first larva egressed also in 29 days. Accordingly, the time spent inside the fruit by any particular larva is not necessarily reflective of development time per se. Under optimal conditions the egg and larva can complete development in 16 days. It would appear that conditions inside the fruit were not uniform, or at least, did not induce uniformity in the behavior of the larvae with respect to egression. Some reports suggest that larvae egress the fruit in response to environmental cues, rather than as a conclusion to the completion of development or depletion of the food source. McPhail & Bliss (1933) likewise found a range of 18 to 35 days for the larval stage in mangoes held in the laboratory. In field-collected mangoes (Cuernavaca, Mexico) left outdoors (exact date of oviposition unknown) the maximum crawl off date was 44 days. They noted that egression from mangoes was stimulated by rainfall, and that this effect could be induced by drumming or vibrating the fruit.

TABLE 1. DURATION OF THE LARVAL STAGE IN GRAPEFRUIT IN AN OUTDOOR ENCLOSURE OVER THE COURSE OF THE YEAR AT WESLACO, TEXAS: FIRST, LAST AND MODAL EGRESS IN DAYS AND DEGREE-DAYS.

Oviposition Date	No. Pupae	Range (Days)	Mode (Days)	First (°D)	Modal (°D)
Jan 03	65	42-59	58	392	565
Jan 26	244	39-56	41	339	360
Feb 16	153	33-52	44	338	470
Mar 09	189	26-36	28	312	338
Mar 23	70	25-32	26	316	334
Apr 13	200	21-39	25	327	402
May 04	41	19-29	27	332	473
Jun 14	7	33-33	33	659	659
Jul 31	32	23-33	33	381	552
Aug 15	117	22-28	22	420	420
Sep 02	177	20-28	26	346	445
Sep 07	192	22-33	27	388	477
Oct 01	231	20-32	28	323	446
Oct 19	9	39-56	41	447	463
Nov 10	66	29-41	32	395	410
Nov 14	25	63-69	63	479	479

Mean °D = 387 ± 87; 456 ± 84.

They reported that in the absence of rainfall the larvae typically egressed in the early morning hours, which would be the time of highest humidity. Thus, one might conclude that in the absence of a specific entrainment, the larvae trickle out of the fruit over a period of weeks rather than making a synchronized mass exodus. In accordance with the findings of Baker et al. (1944), there was no evidence of a gender related difference in development time as has been reported for *Anastrepha suspensa* (Loew) by Sivinski & Calkins (1990). Of the 616 flies which eclosed on the earliest emergence date of each replicate in the Mexican field studies, 317 were females and 299 males.

The actual temporal spread in egression was mainly a function of the number of larvae produced by the fruit. Among the June replicates only one fruit produced larvae and in this fruit only seven larvae completed development. In this case, all larvae egressed on the same day. Evidently the high summer temperatures inhibit survival, possibly because of desiccation of the fruit. Of the twelve replicates between May 24 and August 18, only three produced larvae that egressed and pupariated, while the control fruit in the laboratory each produced in excess of 100 larvae per fruit. By contrast, during the preceding springtime replicates, eleven out of twelve fruit produced larvae. The numbers ranged from 1 to 201 larvae per fruit with a mean of 75 larvae egressing to pupariate per fruit. Not surprisingly, larger numbers of surviving larvae produce a wider egression pattern. This was especially obvious in the control fruit where optimal temperature conditions and a lack of environmental cues triggering egression resulted in as many as 353 larvae developing in one fruit and a spread of as much as 32 days between the first and last larval egress.

Under these circumstances, degree-days was not a good predictor of development time as defined here, time between oviposition and larval egression. Leyva-Vazquez (1988) determined the mean accumulation of degree-days for egg + larval development to be  $291 \pm 57^\circ\text{d}$ . In this study the mean accumulation for the first egressing larvae in each replicate was  $387 \pm 87^\circ\text{d}$  and for the modal egression date,  $456 \pm 84^\circ\text{d}$ . Thus, the larval stage was prolonged relative to that which would be determined from ambient temperature alone and accumulated degree-days was not a good predictor of larval egress. The coefficient of determination ( $r^2$ ) between degree-days and modal egress was only 0.565, and for first larval egress only 0.490. Those values were not much higher than the predictive value of calendar date relative to day length. The coefficient of determination ( $r^2$ ) for day length vs modal egress was 0.448. Reissing et al. (1979) also found the degree-day method to be a better predictor of emergence than mean historical calendar date for the apple maggot.

One well known cause of disparity between degree-day predictions and actual development time is the Kaufmann or Rate Summation effect (Worner 1992). Often in the field, development at low temperatures is faster, and development at high temperatures slower than predicted from laboratory studies. This is especially true of motile, herbivorous insects. Various explanations have been offered to account for this effect (Wagner et al. 1984; Hagstrum & Milliken 1991), but it is unlikely that the Kaufmann effect can be evoked as the cause of the disparity. Firstly, the prolongation of the larval stage occurred even in those replicates wherein the ambient temperatures were far from the extremes at which development was retarded in the laboratory (less than  $9^\circ\text{C}$  or in excess of  $31^\circ\text{C}$ ). Secondly, it is doubtful that the temperatures inside a grapefruit resting on the ground would reach the extremes that were experienced in ambient temperatures. Moreover, since the duration of the larval stage in the controls was also extended beyond the minimum development time with egression spread out over a period of weeks, it is doubtful that any temperature based effect was the dominant factor determining the delay in the date of egress.

In contrast with the results from larval duration, the puparial development time closely paralleled the degree-day predictions from the laboratory studies. Leyva-Vazquez (1988) reported  $316 \pm 10^\circ\text{d}$  mean accumulation between pupariation and adult eclosion. In the field studies conducted at Weslaco the mean puparial stage duration was  $304 \pm 25^\circ\text{d}$  for the first adult eclosion and  $310 \pm 24^\circ\text{d}$  for the modal adult eclosion (Table 2). These values were very close to predicted and thus temperature was the dominant factor determining intra-puparial development time. Furthermore, the correlation between eclosion and degree-day accumulation was very high. For earliest eclosion the coefficient ( $r^2$ ) was 0.966 and for modal eclosion 0.979.

The results obtained from the Mexican portion of the study were more ambivalent. The mean accumulation for the modal egression date at the citrus grove near General Teran was  $329 \pm 42^\circ\text{d}$ , in reasonably close agreement with the results from the laboratory and the Texas field study. However, the mean accumulation for the modal egression date at the mountain canyon site was substantially higher,  $410 \pm 46^\circ\text{d}$ . The

TABLE 2. DURATION OF THE PUPARIAL STAGE IN THE SOIL OF AN OUTDOOR ENCLOSURE OVER THE COURSE OF THE YEAR AT WESLACO, TEXAS: FIRST, LAST, AND MODAL TIME TO ECLOSION IN DAYS AND DEGREE-DAYS.

Pupariation Date	No. Flies	Range (Days)	Mode (Days)	First ( $^\circ\text{D}$ )	Modal ( $^\circ\text{D}$ )
Jan 10	112	43-50	43	345	345
Jan 24	121	36-42	38	277	297
Feb 07	165	29-36	32	284	299
Feb 22	157	29-34	30	289	305
Mar 07	173	28-31	28	313	313
Mar 21	136	22-24	22	281	281
Apr 04	106	22-24	22	302	302
Apr 18	4	21-21	21	313	313
May 02	65	17-18	17	288	288
May 16	1	16-16	16	277	277
May 23	21	14-15	15	283	305
Jun 28	7	15-15	15	279	279
Sep 09	4	18-18	18	329	329
Sep 20	3	16-17	16	271	271
Oct 04	3	16-21	18	276	303
Oct 18	4	31-35	35	316	350
Nov 01	1	35-35	35	336	336
Nov 15	8	36-37	36	326	326
Nov 29	3	43-43	43	323	323
Dec 13	115	45-56	50	322	328
Dec 27	133	49-52	49	349	349

Mean  $^\circ\text{D}$  =  $304 \pm 25$ ;  $310 \pm 24$ .

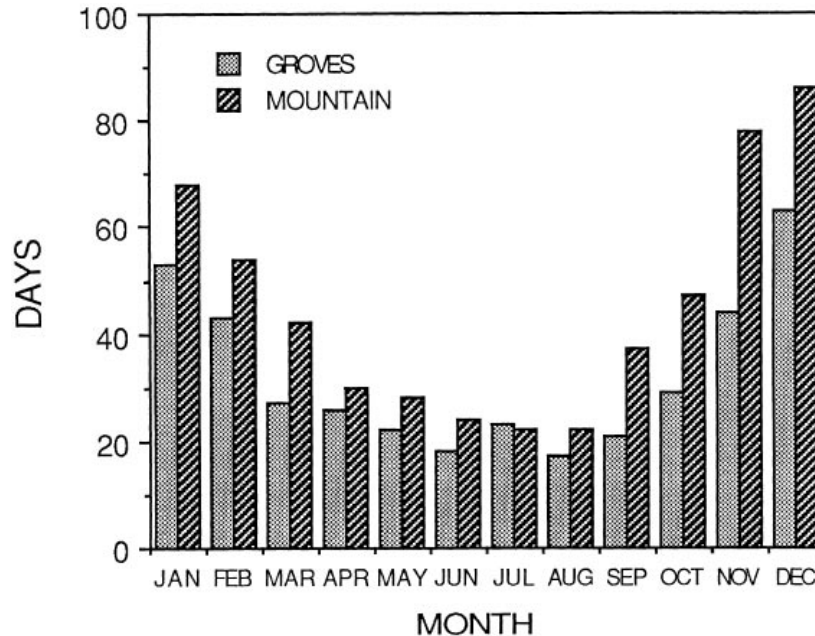


Fig. 1. Length of the puparial stage of the Mexican fruit fly at two localities in northern Mexico: a citrus grove and a mountain canyon.

effect of the slightly cooler mean temperatures at the mountain location is reflected in the graphic representation of these results (Fig. 1). The puparial stage is uniformly prolonged at the higher elevation site relative to the commercial citrus grove location in accordance with expectations. The duration of the puparial stage was shortest (about 3 weeks) during the warmest summer months, and longest during the winter season (prolonged as much as 3 months). Since degree-day accumulations predict this prolongation of the puparial stage, and it can be duplicated in the laboratory, the data suggest that the Mexican fruit fly naturally overwinters in the puparial stage, but not in a true diapause. The greater apparent accumulation of degree-days at the mountain site suggests that actual thermal unit accumulation was less than that calculated by the Means Method. Yellow chapote grows on the east facing slope of the Sierra Madre Oriental, and there may be a montane shadow effect that causes cooler temperatures in the late afternoon compared to the open lowland sites where commercial citrus is cultivated. If so, then an hourly rather than daily heat unit accumulation model may be necessary to predict adult eclosion date in this habitat.

In summary, the results of these studies indicate a significant seasonal effect on generation time. Ultimately the prediction of demographic events such as adult eclosion, seasonality of infestation and number of annual generations will have to incorporate data from the adult reproductive cycle. Temperature is more strongly influential of puparial stage duration than of larval stage duration. Puparial development is so prolonged by low temperatures that overwintering in this stage naturally results without induction of diapause.

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MORTALITY OF *ANASTREPHA SUSPENS*A (DIPTERA:  
TEPHRITIDAE) IN CARAMBOLAS TREATED WITH COLD  
WATER PRECOOLING AND COLD STORAGE

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ABSTRACT

The Caribbean fruit fly, *Anastrepha suspensa* (Loew), is a pest of quarantine significance of carambolas. The fruits are subjected to cold storage quarantine treatment when shipped to areas outside of the known range and where the fly could survive. In this study, rapid cooling in cold water increased mortality of Caribbean fruit fly larvae in carambolas over passive air cooling. Air-cooled carambolas required more than 24 h to cool to the treatment temperature of 1.1°C, while water-cooled fruits required only about 45 min. After 1 day, *Anastrepha suspensa* larvae had greater than 65% mortality in water-cooled carambolas, while mortality of larvae in air-cooled fruits was only 20%. Mortality of larvae in water-cooled fruits was 98% at 4 days, and 100% (1,900 larvae treated) after 9 days. Twenty six larvae were recovered from air-cooled fruits after 4 days (1,900 larvae treated), and one larva after 11 days of treatment. Larval mortality from cold-water-treated fruit reached probit 9 in 8 days, about 2/3 the time (13 days) required for the same level of mortality of larvae in air-cooled fruits. This difference in mortality is probably due to the rapidity of the cooling. It may be possible to use this modification to shorten the current cold treatment of 12 days at 1.1°C for Florida carambolas.

Key Words: Caribbean fruit fly, *Anastrepha suspensa*, commodity treatment, cold storage

RESUMEN

La mosca del Caribe, *Anastrepha suspensa*(Loew), es una plaga de la carambola, *Averrhoa carambola* L., con importancia cuarentenaria. Las carambolas de la Florida son sometidas a tratamiento cuarentenario de almacenaje en frío antes de ser enviadas a lugares donde esa mosca no existe pero tendría posibilidades de sobrevivir. En este estudio, el enfriamiento rápido en agua incrementó la mortalidad de las larvas de la mosca del Caribe en comparación con el enfriamiento pasivo mediante aire. La carambolas tratadas con aire frío requirieron un mínimo de 24 h para alcanzar la temperatura de tratamiento de 1.1°C, mientras que las enfriadas con agua requirieron

solamente cerca de 45 minutos. Después de un día, las larvas de *Anastrepha suspensa* Loew tuvieron más del 65% de mortalidad en las carambolas tratadas con agua fría, mientras que las larvas de frutas tratadas con aire frío tuvieron solamente 20% de mortalidad. Las larvas de las frutas enfriadas con agua tuvieron un 98% de mortalidad a los 4 días y ninguna larva viva (de 1900 tratadas) fue recuperada 9 días después del tratamiento. Veintiseis larvas fueron recuperadas de frutas tratadas con aire frío después de 11 días de tratamiento. La mortalidad de las larvas en las frutas tratadas con agua fría llegó al Probit 9 en 8 días, cerca de 2/3 del tiempo (13 días) requerido por el mismo nivel de mortalidad de las larvas en las frutas tratadas con aire frío. Esta diferencia de mortalidad es probablemente debida a la rapidez del enfriamiento. El tratamiento de agua fría pudiera ser usado para acortar el tiempo de 12 días a 1.1°C actualmente usado para las carambolas de la Florida.

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The carambola, *Averrhoa carambola* L. (Oxalidaceae), is grown throughout the tropics for its oblong, finned fruits. In south Florida the carambola is grown on 215 hectares and the acreage is increasing (Florida Agricultural Statistics Service 1996). The carambola in Florida is a poor host for the Caribbean fruit fly, *Anastrepha suspensa* (Loew) (Swanson & Baranowski 1972). A cold quarantine treatment was developed to market expanded production of carambolas (Gould & Sharp 1990, Gould 1996). Other producers of carambolas have used similar treatments (Armstrong et al. 1995). The present treatment takes 12 d at 1.1°C to produce probit 9 mortality (99.9968% mortality), a standard often used by regulatory agencies in assessing risk of introduction of exotic pests (Shannon 1994). This requires considerable lead time for marketing and shipping fruits, and the cost of keeping the fruits refrigerated at the proper temperature for 12 d is significant.

Many commodities are cooled as soon as they reach the packing house (precooling) to preserve the initial market quality of the product (Hardenburg et al. 1986). This involves rapidly cooling the produce with water, ice, or cold air. In this study we examined the effect of rapidly cooling carambolas with water at  $1.0 \pm .5^\circ\text{C}$  on the mortality of Caribbean fruit fly larvae infesting carambolas.

#### MATERIALS AND METHODS

Carambolas (mean weight  $175 \pm 23.9$  g,  $n = 100$ , 16 count) were obtained from Brooks Tropicals, Homestead, Florida. The carambolas did not have a detectable infestation in the field so they were exposed to approximately 100,000 Caribbean fruit flies in a cage for two days. The infested fruits were held at ambient conditions ( $26 \pm 3^\circ\text{C}$ ) until large 3rd instar larvae developed (6-7 days). This was verified by cutting samples of five fruits.

The carambolas were then divided randomly into two treatment groups of 120 fruits and a control group of 80 fruits. The control was subdivided into 8 groups of 10 fruits. The control was held without any cold treatment and the larvae emerging were used to estimate the population present in the treated fruits. One treatment was not precooled and consisted of carambolas in commercial 16-count cardboard boxes placed directly into a walk-in cooler at  $1.1 \pm .75^\circ\text{C}$ .

For the second treatment, fruits were precooled with cold water. Carambolas were placed in nylon mesh bags ( $15 \times 28$  cm, 35 liters) and immersed in  $0.3 \pm 0.1^\circ\text{C}$  ice water until the fruit core temperatures approximated the water temperature (37-42 min.). The ice water was held in a 209 liter tank with a water circulating pump. Water



temperature was monitored at 5 min intervals with a national standards traceable thermometer, and ice was added as necessary to maintain the temperature of the water. Thermocouples (30-gauge type t copper-constantin) were placed at the centers of three fruits in each treatment. Temperatures were monitored at 5-min intervals. Fruits were removed from the water when all of the monitored center temperatures reached 1.1°C and were placed in 16-count commercial boxes in a walk-in cooler with the other fruit from treatment No.1 ( $1.1 \pm .75^\circ\text{C}$ ). At one-day intervals, 10 carambolas were removed from each treatment up to 12 days. Both treated and control fruits were held over sand for larval emergence. This experiment was replicated five times at one week intervals.

Statistical analysis was performed using probit analysis (SAS Institute 1988) and also by fitting linear and non-linear models using TableCurve 2D (Jandel Scientific 1994).

#### RESULTS AND DISCUSSION

The passively air-cooled carambolas in this experiment required at least 24 h to cool down to the treatment temperature (at 24 h the temperature was  $2.15 \pm .26^\circ\text{C}$ ). Water-cooled fruits cooled down in 40 ( $0.97 \pm .35^\circ\text{C}$ ) to 45 min. ( $0.93 \pm .27^\circ\text{C}$ ). Gould & Sharp (1990) found similar cooling curves, but did not investigate mortality from ice-water cooling.

Infestations in control fruits ranged from 134 to 753 per 80 carambolas, with a mean of 387 and std. dev. of 192. This is an average of 4.8 larvae per fruit with std. dev. of 2.4 larvae per fruit.

The mortality of insects from the two treatments was dramatically different. After one day, larvae in hydro-cooled fruits had greater than 65% mortality, while larvae in air-cooled fruits had about 20% mortality (Fig. 1A). Larvae in water-cooled fruits had 98% mortality at four days, and no larvae (from approximately 1900 larvae treated) were recovered more than 9 days after treatment. Twenty six larvae were recovered from air-cooled fruits (from approximately 1900 treated) after 8 days of treatment, and one larva was recovered after 11 days of treatment. These differences are lessened when the data are shifted one day to take into account the time it takes air-cooled fruits to cool down to treatment temperature (Fig. 1B).

The probit transformation gave the best 'fit' for the data of equations tested (using the f statistic and Tablecurve which fits 3000+ equations). Predictions for 75, 90, 99 and 99.9968% mortality are given in Table 1. Both the predictions for probit 9 for larvae in air-cooled and the shifted air-cooled fruits are close to that found by Gould & Sharp (1990). The prediction for larvae in water-cooled fruits differs greatly from predictions of mortality for larvae of either of the air-cooled data sets and the 95% fiducial limits do not overlap indicating the differences are significant. Probit 9 mortality in cold-water treated fruits was reached in just over half the time (59.8%) in air-cooled fruits. This difference in mortality is probably due to the rapidity of the cooling rather than water immersion. Taschenberg et al. (1974) found that Caribbean fruit fly larvae could survive 24 h with low mortality in water, so the water itself probably did not have a major effect on the mortality of the larvae.

Hallman (1994) found that rearing temperature did not significantly effect the mortality of Caribbean fruit fly larvae treated at 1°C. The coldest rearing temperatures used in that study, 20°C, may not have been cold enough to bring about a physiological acclimation response in the insect. Other studies have shown that in some species of flies, adults can acclimate to cold temperatures (Meats 1976, Czajka & Lee 1990, Chen & Walker 1994).

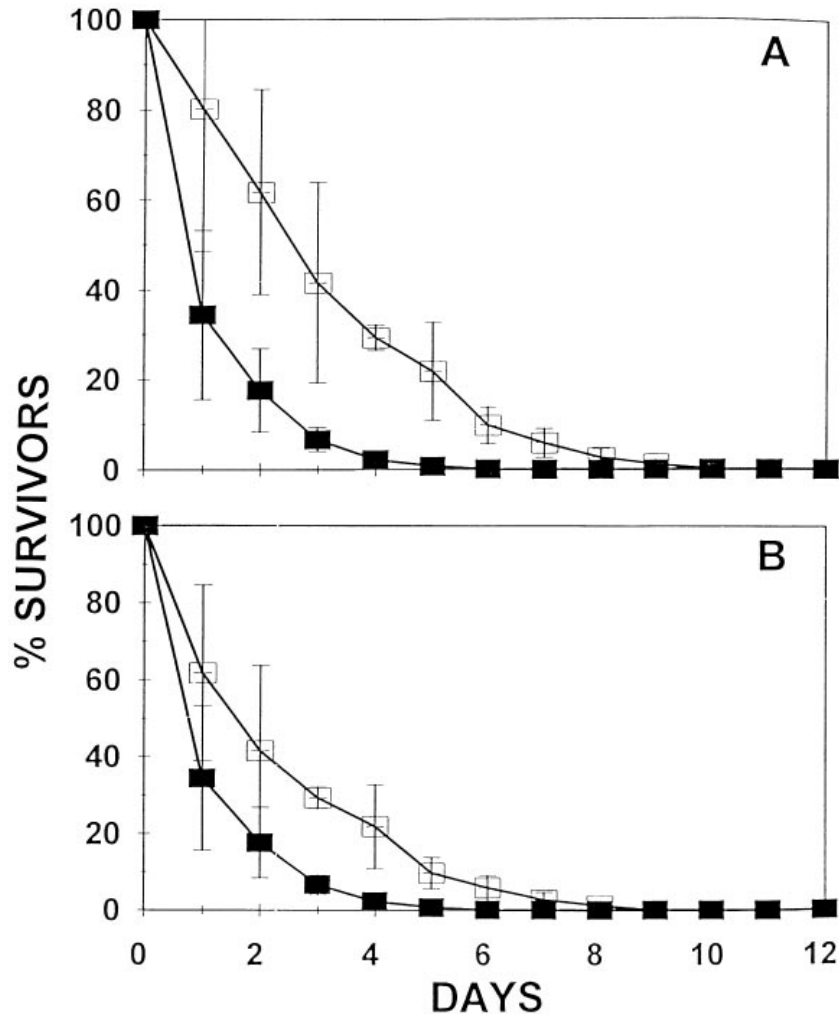


Fig. 1. Survivorship of (A) Caribbean fruit fly larvae in carambolas treated with cold water (solid square) and cold air (open square). Survivorship of (B) Caribbean fruit fly larvae in carambolas treated with cold water (solid square) and cold air (open square) adjusted by subtracting one day from cold-air treatment time to account for delayed cooling time.

The mortality of larvae over the longer period of time is presumed to be due to factors other than cold shock. Lee (1991) referred to this type of mortality as 'indirect chilling injury' with the mechanism of death presumably due to depletion of cellular resources. Lee (1991) termed the short term type of mortality as direct chilling injury or cold shock. Postulated mechanisms for cold shock include breakdown of the lipid portions of the cell wall in the temperature range of 1-2°C which allows the cellular contents to leak (Lee & Chapman 1987).

TABLE 1. MORTALITY ESTIMATES FROM COLD TREATMENTS.

Treatment	Mortality	Estimate (Days)	95% Fiducial Limits	
			Lower	Upper
Water-Cooled	75%	1.65	1.11	2.06
	90%	2.80	2.38	3.39
	99%	4.78	4.02	6.21
	99.9968%	7.94	6.44	10.95
Air-Cooled	75%	4.48	4.17	4.80
	90%	6.08	5.69	6.56
	99%	8.84	8.18	9.71
	99.9968%	13.27	12.09	14.82
Air-Cooled Shifted 1 d	75%	3.35	3.13	3.56
	90%	5.14	4.88	5.43
	99%	8.21	7.73	8.80
	99.9968%	13.14	12.22	14.28

The more rapid mortality of larvae in water-cooled fruits was probably from cold shock including the lack of time for the larvae to acclimate to the cold temperatures.

Whatever the mechanism of death, this study has shown that rapid cooling brings about rapid mortality. It may be possible to incorporate this into the current cold treatment of 12 days at 1.1°C for Florida carambolas and reduce treatment time substantially. Reductions in the treatment may make the treatment less costly and also less damaging to the fruits.

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CONTROL OF *SOLENOPSIS INVICTA*  
(HYMENOPTERA:FORMICIDAE) WITH TEFLUBENZURON

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ABSTRACT

Teflubenzuron baits were active against laboratory colonies of the red imported fire ant, *Solenopsis invicta* Buren. Worker brood production ceased soon after treatment and by four weeks posttreatment, most colonies were devoid of brood. Worker ants did not exhibit any direct effects from treatment with teflubenzuron. As is typical with most insect growth regulators, colony mortality was slow and dependent on old-age attrition of the worker ants. A few (<25) female alates were produced in one of the laboratory colonies at 12 weeks posttreatment.

The teflubenzuron baits reduced field colonies of *S. invicta* by 75-79% within 6 weeks after treatment, 83-86% within 13 weeks, and 77-91% within 17 weeks. At 17 weeks posttreatment, the presence of worker brood in the plots treated with the lower rates, 0.1125% and 0.0225%, gave evidence of recovery of some colonies. However, the results of the field tests indicate that teflubenzuron has excellent potential for control of field populations of *S. invicta*.

#### RESUMEN

Los cebos de teflubenzuron fueron activos contra colonias de laboratorio de la hormiga roja importada de fuego, *Solenopsis invicta* Buren. La producción de obreras cesó en breve tiempo después del tratamiento, y a las 4 semanas la mayoría de las colonias quedó desprovista de ellas. Las obreras no mostraron efectos directos del tratamiento con teflubenzuron. Como es típico en la mayoría de los regladores del crecimiento de insectos, la mortalidad de la colonia fue lenta y dependiente del desgaste por edad de las obreras. Unas pocas (<25) hembras aladas fueron producidas en las colonias de laboratorio a las 12 semanas del tratamiento. Los cebos de teflubenzuron redujeron las colonias de campo de *S. invicta* en un 75-79% en 6 semanas, en un 83-86% en 13 semanas, y en un 77-91% en 17 semanas después del tratamiento. A las 17 semanas del tratamiento, la presencia de obreras inmaduras en las parcelas tratadas con las dosis más bajas, 0.1125% y 0.0225%, fue una evidencia de la recuperación de algunas colonias. Sin embargo, los resultados de pruebas de campo indicaron que teflubenzuron tiene un excelente potencial para el control de poblaciones de campo de *S. invicta*.

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Insect growth regulators (IGRs) are highly active against the red imported fire ant, *Solenopsis invicta* Buren, (Banks 1986, Banks et al. 1978, 1983, 1988, Phillips et al. 1985, 1989, Vinson & Robeau 1974, Vinson et al. 1974). The most effective IGRs prevent the replacement of the worker caste in colonies through mortality of developing immatures, degeneration of the reproductive organs of the queen, and/or a shift in caste differentiation from worker to sexual forms. This lack of worker replacement usually results in colony death because the existing worker ants die and dependent castes and immatures succumb from neglect. Juvenile hormone mimics have been the most effective IGRs, and two of these materials, fenoxycarb and 1-(8-methoxy-4,8-dimethylnonyl)-4-(1-methylethyl) benzene, have been used in commercial baits for fire ant control.

Another group of IGRs, i.e. Benzoylphenyl urea (BPU) compounds, of which diflubenzuron (dimilin) is the best known, has been successfully developed as control agents for a number of other insects. These chemicals are commonly known as chitin inhibitors because they interfere with normal endocuticular deposition and molting in insects. They also are ovicidal in some cases. Because of the low solubility of the BPUs in soybean oil or other food attractants, this group of IGRs has not been used successfully against fire ants. A newer BPU, teflubenzuron [1-(3,5-dichloro-2,4-difluorophenyl)-3-(2,6-difluorobenzoyl)-urea] (American Cyanamid Co., Wayne, NJ 07470 USA), is much more soluble in food attractants and may offer promise in fire ant management systems. Teflubenzuron is considerably more physiologically active than diflubenzuron against a number of agricultural pests and has effectively controlled some insects, such as the diamondback moth, *Plutella xylostella* (Linnaeus), and the red flour beetle, *Tribolium castaneum* (Herbst), that are highly resistant to other types of insecticides (Ishaaya & Klein 1990). Herein, we report the results of laboratory and field studies with teflubenzuron against *S. invicta*.

## MATERIALS AND METHODS

## Laboratory Tests

Three laboratory tests were conducted with laboratory-reared queenright *S. invicta* colonies (Banks et al. 1981). For each test, teflubenzuron (10% emulsifiable concentrate) was combined with once-refined soybean oil to produce baits containing 0.1% and 0.5% active ingredient (wt/wt). In each test, three colonies were exposed to 0.5 ml of each bait concentration. The 0.1% solution (0.5 mg per colony AI) and the 0.5% solution (2.5 mg per colony AI) were tested against colonies with 20-25 ml brood and 20,000-40,000 workers, and 30-35 ml brood and 50,000-70,000 workers, respectively. Three colonies were exposed to 0.5 ml of neat once-refined soybean oil and served as non-treated controls. The test colonies were allowed ad libitum feeding on the oil solutions which were offered in micropipets. The colonies were returned to normal diet (Banks et al. 1981) 24 h after treatment and maintained in the laboratory at  $27 \pm 2^\circ\text{C}$ . Monthly observations (including numbers of workers, reproductives, and amount of brood) were made until the colonies died, returned to their normal pre-treatment index level, or for one year, whichever occurred first.

Effectiveness of the treatments was based on comparison of the before and after treatment size index of each colony. This index was derived by multiplying the assigned values for worker numbers, i.e. 1-6, by the quantity of worker brood, i.e. 1-25, (Table 1); e.g. a colony with a rating of 5F would have a colony index of 125 ( $5 \times 25$ ) (Banks & Lofgren, 1991). For each of the three tests, data were combined for the three colonies. Mean percent reduction in colony indices were analyzed using an analysis of variance and Tukey's Studentized Range (HSD) test (SAS Institute 1988).

## Field Tests

Pregel defatted corn grit baits containing 0.01125, 0.0225, or 0.045% teflubenzuron were prepared in our laboratory for the field tests as follows. Technical teflubenzuron (97.5%) was dissolved in dimethyl formamide (0.5-1.5% by weight of oil in the formulation) and the solution was incorporated into warm (20-25°C) once-refined soybean oil. The oil solution was slowly poured over the corn grits as they were stirred in a large food mixer. Stirring continued for about 10 minutes to insure thorough mixing of the oil and grits.

TABLE 1. VALUES FOR CALCULATION OF COLONY INDEX OF LABORATORY COLONIES OF *S. INVICTA*.

Estimated Number of Worker Ants	Estimated Quantity of Worker Brood (gms)					
	Rating	Value	Rating	Value	Rating	Value
<100	1	1	0	A	1	
101-5000	2	2	1-5	B	5	
5001-20000	3	3	5-10	C	10	
20001-35000	4	4	10-20	D	15	
35001-50000	5	5	20-30	E	20	
>50000	6	6	>30	F	25	

Each bait was broadcast with a tractor-mounted granular applicator (Williams et al. 1983) at a rate of 1.12 kg/ha on 0.2-ha plots with an average of 12 mounds per hectare in nongrazed permanent pasture in Union County, Florida. Three plots were treated with each teflubenzuron concentration; three plots were treated with Logic (fenoxycarb, Ciba-Geigy, Greensboro, NC) at a rate of 1.12 kg/ha as a standard, and three plots were left untreated as a control. Efficacy of the treatments was evaluated by comparison of the before and after (6, 13 and 17 weeks) treatment population indices using standard methods established for determination of population indices of *S. invicta* (Banks et al. 1988). Mean reductions in population indices were analyzed using an analysis of variance and Tukey's Studentized Range (HSD) test (SAS Institute 1988).

## RESULTS AND DISCUSSION

### Laboratory tests

Teflubenzuron was very active against laboratory colonies of *S. invicta* (Table 2). In test one, worker brood production ceased soon after treatment and by four weeks post-treatment two colonies at the 0.5 mg dosage were devoid of brood and only a few pupae remained in the third colony. All colonies at the 2.5 mg rate were devoid of brood at four weeks. The only worker brood production thereafter through the one-year test occurred in one colony at the 0.5 mg rate; about 0.5 ml was present at the one-year posttreatment evaluation. In test one, all three colonies subjected to the 2.5 mg rate died by 36 weeks; however, two colonies at the 0.5 mg rate were alive at one year, although neither contained more than 500 workers and only one colony had a queen present. It is doubtful that these colonies would have survived under field conditions.

Colony reduction did not occur as quickly in the second test. All three colonies treated at 0.5 mg and two treated at 2.5 mg still contained some worker brood at four weeks; however, all treated colonies were devoid of worker brood by eight weeks and remained so until the test was discontinued after 32 weeks. At the conclusion of test two, fewer than 500 workers remained alive in any treated colony.

In test three, with the exception of one 0.5 mg treatment, all colonies at both dosages (0.5 mg and 2.5 mg) were devoid of worker brood by sixteen weeks and remained so until the test was discontinued after 32 weeks. The one colony at 0.5 mg still had worker brood present until the end of the test. At the end of test three, fewer than 100 workers remained alive in any treated colony with all colonies having fewer than 25 workers, including one colony at 0.5 mg that contained a small amount of brood. All of the queens in the treated colonies were dead or were not producing eggs except one colony treated with 0.5 mg.

Worker ants did not exhibit any direct effect of treatment with teflubenzuron in any test. Thus, as is typical with most insect growth regulators, colony mortality was slow and dependent on old-age attrition of the worker ants. No alate production occurred in any of the treated colonies in test one and test three; however, in test two, a few (<25) female alates were produced at 12 weeks posttreatment in two replicates at the 2.5 mg rate.

The untreated colonies in test one showed no change or increase in size through 24 weeks posttreatment, but began a decline thereafter that left all three devoid of worker brood and reduced in size by one year. The controls in test two began a decline at 12 weeks that resulted in termination of the test after 32 weeks. The control colonies in test three were significantly different than the treatments until week 16. After this time, although they were noticeably different containing large physogastric



TABLE 2. EFFECTIVENESS OF TEFLUBENZURON AGAINST LABORATORY COLONIES OF *S. INVICTA*.

Dosage (mg/Colony)	Pretreatment Colony Index	% Reduction in Colony Index after Week <sup>1</sup>									
		4	8	12	16	20	24	32			
0.5	101.7a	92.8a	97.0a	Test 1			97.9a	98.2a	98.2a	98.2a	98.2a
				97.3a	97.3a	97.9a					
				96.7a	98.2a	98.5a					
2.5	150.0a	90.7a	96.7a	Test 1			97.9a	98.7a	98.7a	98.9a	98.9a
				97.3a	97.3a	98.2a					
				-1.7b	-15.0b	-15.0b					
CK	131.7a	-8.3b	-1.7b	Test 1			-15.0b	-15.0b	-15.0b	25.0a	25.0a
				97.3a	97.3a	97.9a					
				96.7a	98.2a	98.5a					
0.5	133.3a	83.8a	97.2a	Test 2			98.5a	98.5a	98.5a	98.5a	— <sup>2</sup>
				98.0a	98.0a	98.3a					
				98.0a	98.0a	98.0a					
2.5	150.0a	87.5a	96.5a	Test 2			98.2a	98.2a	98.5a	98.5a	—
				98.0a	98.0a	98.0a					
				29.2a	23.9a	23.9a					
CK	140.0a	-8.3b	-8.3b	Test 2			23.9a	23.9a	23.9a	23.9a	—
				98.0a	98.0a	98.3a					
				98.0a	98.0a	98.0a					
0.5	142.0a	82.2a	97.2a	Test 3			98.1a	98.6a	98.6a	96.9a	96.9a
				97.9a	97.2a	98.1a					
				97.2a	97.5a	97.7a					
2.5	132.0a	95.9a	96.9a	Test 3			97.7a	98.2a	98.2a	95.8a	95.8a
				97.2a	97.2a	97.5a					
				-8.3b	-8.3b	-8.3b					
CK	140.0a	5.6b	5.6b	Test 3			23.7a	24.3a	24.3a	25.0a	25.0a
				97.9a	97.2a	98.1a					
				97.2a	97.5a	97.7a					

<sup>1</sup>Means within columns followed by the same letter are not significantly different ( $P < 0.05$ ),  $N = 3$  using Tukey's HSD test on arcsine transformed data.

<sup>2</sup>Observations were made at 32 wks but data were not included because of high check mortality.

TABLE 3. EFFECTIVENESS OF TEFLUBENZURON BAITS AGAINST FIELD POPULATIONS OF *S. INVICTA*.

Bait	Application rate		Pretreatment		% Reduction in Population Index after Indicated Weeks <sup>1</sup>		
	Bait (kg/ha)	AI (g/ha)	No. mounds	Pop'n index	6	13	17
Teflubenzuron 0.01125%	1.12	0.051	37	788	78.3a	83.4a	77.5a
Teflubenzuron 0.0225%	1.12	0.102	37	877	75.5a	84.3a	80.6a
Teflubenzuron 0.045%	1.12	0.204	36	809	79.0a	86.2a	91.3a
Logic (standard) 1.0%	1.12	4.53	39	866	81.8a	92.4a	97.9a
Control	—	—	29	675	-17.0b	11.1b	14.7b

<sup>1</sup>Means within columns followed by the same letter are not significantly different ( $P < 0.05$ ).  $N = 3$  using Tukey's HSD test on arcsine transformed data.

queens, large amounts of brood, and numerous workers, the colony indices were not statistically different.

Significant ( $P < 0.05$ ) reductions in colony indices of treated colonies compared with untreated controls were observed from 4-24 weeks in test one, up to 8 weeks in test two and from 4-12 weeks in test three. These results indicated that the reductions were caused by teflubenzuron and not attributable to a decline observed in the untreated controls late in the tests. The decline in the control colonies is not readily explainable; however, they might have been inadvertently exposed to teflubenzuron over the long test period. Food and water tubes for all of the colonies, both treated and controls, were handled using the same gloves and forceps. This technique has not appeared to affect control colonies in other tests with chemicals. However, teflubenzuron is biologically effective at extremely low dosages and they may have been exposed to minute residues in these tests.

#### Field tests

The teflubenzuron baits reduced the population indices of field colonies of *S. invicta* by 75-79% within 6 weeks after treatment (Table 3). No significant difference was noted in the effectiveness of any of the teflubenzuron baits or the Logic standard at either the 6 or 13 week evaluation. By 17 weeks, however, the presence of worker brood in 6 and 5 colonies, respectively, in plots treated with the 0.01125% and 0.0225% baits gave some evidence of recovery. No surviving colonies in plots treated with the 0.045% teflubenzuron or Logic baits contained any worker brood after 17 weeks. The number of workers in the surviving colonies after 17 weeks had been substantially reduced at the highest dosage of teflubenzuron with 82.1% of the colonies having <10,000 workers, 48.1% having <1,000 which was not statistically different than Logic standard (100% of the colonies had <10,000 workers, 91.7% had <1,000 workers).

The results of the field tests indicate that teflubenzuron has excellent potential for control of field populations of *S. invicta*. The levels of teflubenzuron tested in the field were extremely low when compared with Logic; therefore, higher levels of teflubenzuron may produce even better control.

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*MELIA AZEDARACH* EXTRACT AS AN ANTIFEEDANT TO  
*BEMISIA TABACI* (HOMOPTERA: ALEYRODIDAE)

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*Melia azedarach* (L.) is a tree of the family Meliaceae native to India and introduced to Brazil many years ago. The insecticidal property of meliaceous plants has been known for quite a long time (Kraus et al., 1987). Another plant of the same family, the neem tree, *Azadirachta indica*, is known for its insect antifeedant and/or insect growth regulation activity (Schumuterer, 1990).

Tests carried out under screen-house conditions showed that *M. azedarach* aqueous extract interfered with the transmission of bean golden mosaic virus (BGMV) by *Bemisia tabaci* (Genn.). The transmission efficiency of this virus by the vector was reduced by 95% in the acquisition or inoculation tests, although the extract had no insecticidal action. The extract interference was also observed under field tests, reducing transmission by 45-60% compared to the control plants (Nardo & Costa, 1990). These results were attributed to a phago-deterrent effect of the plant extract, although a toxic action on the *B. tabaci* was possible.

The purpose of the present study was to verify whether or not *M. azedarach* extract could affect feeding and colonization on bean plants by *B. tabaci*.

The tests were carried out under screen-house conditions at Campinas, State of São Paulo, Brazil. *B. tabaci* was collected from a colony reared on soybean plants in a screen-house in the same region. Test plant was the common bean, *Phaseolus vulgaris* L., cv. Carioca, with 2 primary leaves per plant and 2 plants per pot.

The extraction procedure was conducted using an aqueous cold infusion of equal parts of leaves and ripe fruits at the rate of 1:5 (w/v). Leaves and fruits were blended with water and maintained in a glass container for 24 h after which the infusion was filtered through a fine cloth and used for spraying. Two experiments were conducted with the extract.

The objective of the first experiment was to determine the mortality of *B. tabaci* caused by *M. azedarach* extracts. It consisted of 3 treatments with 3 replications at 3 different times. Each experiment consisted of 25 adult *B. tabaci* of uniform age (1 day) confined in a glass cage (12 × 8 cm) over a pot with 2 bean plants sprayed with *M. azedarach* aqueous extract (treatment 1); 2 bean plants sprayed with water (treatment 2); and no plants, just soil (treatment 3). The numbers of live insects was counted daily until the last one died.

The objective of the second experiment was to evaluate whether or not oviposition of *B. tabaci* would be affected by treating plants with *M. azedarach* extract. The experiment consisted of 2 treatments and 3 replicates. Each experimental unit consisted of 10 bean plants sprayed with *M. azedarach* extract (treatment 1) or water (treatment 2). Potted plants (with 2 primary leaves) were exposed to a dense population (more than 5 × 10<sup>3</sup>) of *B. tabaci* adults reared on soybean plants. After 72 h the plants were moved to a different screen-house (all adult *B. tabaci* had been removed from the

TABLE 1. MORTALITY (%) OF ADULT *BEMISIA TABACI* UNDER DIFFERENT TREATMENTS.

Treatments	Mortality % <sup>1</sup>		
	48h	72h	96h
Bean plants sprayed with <i>M. azedarach</i> extract	70a	90a	100a
Bean plants sprayed with water	30b	40b	50b
No plant substrate	95a	100a	100a

<sup>1</sup>In each row, values followed by the same letters are not significantly different at 5% level (Tukey's test).

leaves). The numbers of "pupae" of *B. tabaci* on primary leaves were counted, and the adult emergence was evaluated 30-45 days later.

In the first experiment, rates of mortality of *B. tabaci* on plants sprayed with extracts were not significantly different from rates of mortality when *B. tabaci* was kept unfed (Table 1). However, those rates were significantly higher than the rates on plants sprayed with water. On those plants, some *B. tabaci* were still alive 10 days after the beginning of the experiment.

In the second experiment the number of "pupae" of *B. tabaci* on plants sprayed with *M. azedarach* aqueous extract was significantly lower than on plants sprayed with water (Table 2). Pupal development, however, was the same on both kind of plants.

The results obtained in the first experiment suggest a possible antifeedant action of the *M. azedarach* extract as the insects without food died at a similar rate. Studies of plants of the family Meliaceae have resulted in the isolation of many limonoids with insect antifeedant and insecticidal properties (Kraus & Cramer, 1981, Kraus et al, 1987). Volkonsky (1937) reported that leaf extracts of *M. azedarach* sprayed on other plants protected them against locust feeding. Similar results were observed in Brazil by Lepage et al. (1946). Nardo (1989) attributed a considerable reduction of the infection level of BGMV, a circulative virus in *B. tabaci*, to an antifeedant activity of *M. azedarach* on the vector. Also, Nardo & Costa (1990) demonstrated that the antifeedant effect of *M. azedarach* extract was not effective enough to prevent transmission of a non-circulative virus by *B. tabaci*, probably because it could not prevent probing of the leaves by the insect. This antifeeding action seems to be very specific to *B. tabaci* be-

TABLE 2. TOTAL NUMBER OF PUPAE OF *BEMISIA TABACI* ON PRIMARY LEAVES OF 30 BEAN PLANTS SPRAYED WITH *MELIA AZEDARACH* AQUEOUS EXTRACT.

Test Number	Number of Pupae <sup>1</sup>	
	Control Leaves	Sprayed Leaves
1	890a	401b
2	742a	384b
3	821a	418b

<sup>1</sup>In each row, values followed by the same letters are not statistically different at 5% level (Tukey's test).

cause Nardo(unpublished), observed that the transmission of two viruses (circulative and non-circulative) by *Myzus persicae* was not affected by *M. azedarach* extracts.

The results obtained in the second test indicate that *M. azedarach* extracts could have affected the number of eggs laid and the corresponding number of "pupae" produced, probably because of its antifeeding action. That could be explained by the fact that oviposition by *B. tabaci* occurs normally when the insect is feeding on the plant (Gamell, 1974).

The *M. azedarach* extract could interfere in field spread of BGMV directly by reducing feeding and, consequently, the transmission efficiency of this virus by the vector (Nardo, 1990) and indirectly by reducing the population of *B. tabaci*.

The authors wish to thank G. J. de Moraes, CNPMA-EMBRAPA, for reviewing an earlier version of this paper.

#### SUMMARY

Tests conducted under glass-house conditions indicated that aqueous extracts of *Melia azedarach* applied on bean plant leaves interfere with longevity and development of immature stages of *Bemisia tabaci* (Genn.). That effect could reduce the transmission efficiency of bean golden mosaic virus by the vector.

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NOTES ON IDENTIFICATION AND ECOLOGY OF TUMBLING  
FLOWER BEETLES (MORDELLIDAE) FROM OSSABAW  
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A unique opportunity on April 25, 1995, to intensively search for mordellid beetles resulted in finding four species on Ossabaw Island, Chatham County, Georgia. This is the first report of their host plant associations and the sympatry of *Mordellistena trifasciata* and *M. minuta*. Historically, there has been confusion between these two species (Liljeblad 1945, Khalaf 1971) because their elytral color patterns are practically identical. I provide some overlooked distinctions between them.

*Mordellistena pubescens* (Fabricius) (Fig. 1): 6 specimens on black cherry *Prunus serotina* (Rosaceae), sparkleberry *Vaccinium arboreum* (Ericaceae), and wax myrtle *Myrica cerifera* (Myricaceae).

According to Liljeblad (1945), the color patterns of this species are quite variable. The dermal color of the Ossabaw specimens varies from reddish brown to black. There are three (sometimes four) dark spots surrounded by cinereous pubescence on the basal half (posterior) of the pronotum. Cinereous pubescence totally covers the anterior portion of the pronotum.

The elytral markings of golden pubescence in the Ossabaw specimens are inconsistent with those illustrated by Liljeblad (1945). Because both base and apex are covered with golden pubescence, there appear four golden crossbands on the elytron. The lateral margins are heavily covered with golden pubescence that encloses three dark spots on the elytron. The middle dark spot is usually more or less a crossband. In one specimen, the apical dark spot is so heavily encroached by the apical and penultimate golden crossbands that it is almost obliterated.

The short oblique ridges on the posterior tibia vary from 2-6 with the apical two obvious and the basal remainder rudimentary; the basitarsus has 2-4 ridges, again only the apical two are obvious; the second tarsal segment has only one ridge with a rudimentary second barely visible. These counts by Liljeblad (1945) are 3-4, 3, and 2, respectively. Determination of the number of ridges on the posterior leg is therefore highly subjective.

*Mordellistena andreae andreae* Leconte (Fig. 2): 10 specimens on black cherry *Prunus serotina* (Rosaceae), sparkleberry *Vaccinium arboreum* (Ericaceae), wax myrtle *Myrica cerifera* (Myricaceae).

Liljeblad (1945) named three varieties of this species. The form *M. ancilla*, regarded as a variety of *M. andreae* (Liljeblad 1945, Bright 1986), was said by Khalaf (1971) to have the penultimate segments of the anterior and middle tarsi truncated at apex. These segments on all Ossabaw specimens are slightly emarginate or notched at apex. This may be why Khalaf called *ancilla* a full species.

Head and thorax are yellow in the male and black in the female of *M. andreae andreae*. However, one female from Ossabaw has a totally ferruginous head. Liljeblad (1945) also reported "female with black head except a space in front of antennae which is yellowish." Apparently female head color is variable in this form.

*Mordellistena trifasciata* (Say) (Fig. 3 & Table 1): 2 specimens on red buckeye *Aesculus pavia* (Hippocastanaceae) and sparkleberry *Vaccinium arboreum* (Ericaceae).



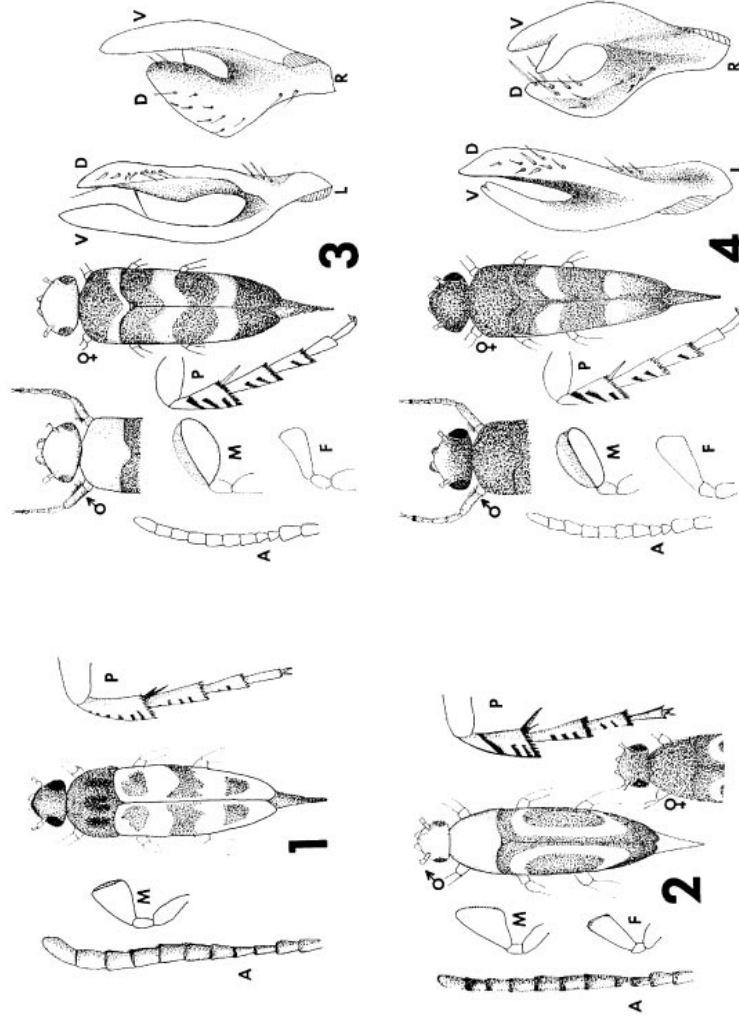


Fig. 1-4. *Mordellistena pubescens*, *M. andreae*, *M. trifasciata*, and *M. minuta*, respectively. A, antenna; M, male maxillary palp; F, female maxillary palp; P, posterior leg; L, left parameron; R, right parameron; D, dorsal branch; V, ventral branch. For paramera, top is apex.

TABLE 1. SOME DIFFERENCES BETWEEN *MORDELLISTENA TRIFASCIATA* AND *M. MINUTA*.

Difference	<i>M. trifasciata</i>	<i>M. minuta</i>
Head	Male yellow	Male black with yellow frons
Pronotum	Female yellow	Female black
	Male yellow	Male black
Male right parameron	Female black with yellow basal edge	Female black
	Ventral branch simple	Ventral branch with bifurcation
Male left parameron	Deeply branched from base	Apical half branched
Habitat	Shrubs	Low weeds

Liljeblad (1945) stated that there were long seta-like hairs on the anterior femur in males. These hairs are in fact located on the inner side of the anterior tibia, from the joint with the femur to halfway down the tibia.

The left parameron has no basal prominence (Franciscolo 1957) on its dorsal branch, and is deeply branched from base on. The dorsal branch of the left parameron has three setae at outer base facing the inner surface of the right paramera. The dorsal branch of the right parameron is wider and much shorter than the ventral branch.

*Mordellistena minuta* Smith (Fig. 4 & Table 1): 4 specimens on a broadleaf roadside weed (Compositae?).

Khalaf (1971) correctly pointed out that as in *M. trifasciata*, the last segment of the male maxillary palp is boat-shaped or malleiform and that there is only one posterior tibial spur. Liljeblad (1945) overlooked these two characters. Both Liljeblad (1945) and Khalaf (1971) overlooked the seta-like hairs on the anterior tibia in males, which are located as in *M. trifasciata*, but fewer.

The left parameron has no basal prominence on its dorsal branch, and is only branched on the apical half. The dorsal branch of the left parameron has also three setae at outer base facing the inner surface of the right paramera. Its ventral branch has a small dent at tip, and is shorter than the dorsal branch. The ventral branch of the right parameron is strongly bifurcated, very atypical of male genitalia of *Mordellistenini* (Franciscolo 1957).

Liljeblad (1945) claimed that the basal (upper) ridge of the posterior tibia of *M. minuta* was longer than that of *M. trifasciata*, "extending nearly across the outer face." He primarily separated the two species in keys using the length of this basal ridge. However, he described great variation of the ridge length in *M. trifasciata*. In all Ossabaw specimens the length and form of this basal ridge of *M. minuta* is the same as in *M. trifasciata*. This will not separate the two species. Some major differences between the two are shown in Table 1.

This project was funded by Earthwatch, the Ossabaw Island Foundation, and The Conservation Agency. I thank E. West, S. and R. Parker, J. Lazell, P. Logan, and P. Perkins.

## SUMMARY

*Mordellistena pubescens*, *M. andreae*, *M. trifasciata*, and *M. minuta* and their host plants are first recorded from Ossabaw Island, Georgia. For the latter two closely re-

lated species, sympatry and morphological, genitalic, and ecological distinctions are first reported here.

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CROZIER, R. H., AND P. PAMILO. 1996. *Evolution of Social Insect Colonies: Sex Allocation and Kin Selection*. Oxford Univ. Press, Oxford. viii + 306 p. ISBN 0-19-854942-3. Paperback. \$35.00.

I had the privilege to be a graduate student in the late 1970s when the more modern stages of the neo-Darwinian synthesis were under frenetic construction. Excite-

ment, compelling theories and occasional data were the materials at hand for laying the foundations of Sociobiology and Behavioral Ecology. People lost considerable sleep pondering the grim intricacies of parental manipulation and the sudden understanding of kin-selection could arrive like a religious revelation.

Among the most respected thinkers of The Movement was Robert Trivers, a genius, then at Harvard, who regularly elucidated evolutionary concepts that altered many a consciousness. In 1976 he and H. Hare published what, in retrospect, seems to have been one of the last great ideas of the time. Social insects were, so to speak, on everyone's mind. They had proved to be important both as protagonists in the thought experiments of pioneering theorists and as subjects for the experimentalist who had begun to test the novel predictions the new theories had generated. Trivers and Hare had appreciated that sex ratios in ants could help resolve which of the competing theories of "parental manipulation" or "kin-selection" was best able to explain the evolution of eusociality, an issue understood to have implications beyond the Hymenoptera. Their predictions arose from haplodiploid sex determination creating asymmetries of relatedness. Simply stated, they argued that under kin selection queens and workers would be lead to invest differently in sons / brothers and daughters / sisters, i.e., a kin-selected colony under worker control could be recognized by its disproportionate production of females.

Criticism of Trivers and Hare came swiftly. Not the least of the objections concerned the usefulness of the data they used to support their hypothesis. However, there was a general feeling that with a little more time the required data would be collected and the issue concluded. This collection proved to be more complex than anyone imagined and 20 years later the question of who runs social insect colonies, the queens or the workers, is still an important theme of this very well written and interesting book by Ross Crozier and Pekka Pamilo.

The authors introduce their book by posing 3 major questions: 1) Who reproduces in the colony? 2) How are resources allocated between reproductive and non-reproductive functions (i.e., between the production of reproductives and colony growth and maintenance)? and 3) How are resources allocated between male and female functions? In the course of addressing these questions the authors first examine the concept of inclusive fitness, including such issues as caste determination. They then consider the evolution of eusociality in insects, and in the process offer explanations for striking phenomena such as the absence of male workers in the Hymenoptera contrasted with their presence in the Isoptera. Next is a discussion of the evolution of colony characteristics, which include worker reproduction and queen mating frequencies. This is followed by an examination of intra-colony conflicts over sex-allocation and finally a survey of colony-level variation of sex ratios.

The book is a product of a mature field, i.e., it contains a wealth of detail and a considerable amount of mathematics. The latter should not discourage natural historians with an interest in the former. The authors have the happy ability of presenting complex arguments in prose and there are graphs to help visualize some of the more difficult concepts. The literature review alone will be of value to those intrigued with insects or social behavior. It would not take away from the drama of reading the book to hint that there is a great deal more to be done before the relationship between sex allocation and kin selection is fully understood.

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CIBRIAN T., C., J. T. MENDEZ M., R. CAMPOS B., H. O. YATES, III, AND J. FLORES L. 1995. *Insectos Forestales de México/Forest Insects of Mexico*. (North American Forestry Commission, FAO, Publication no. 6). Universidad Autónoma Chapingo, Chapingo, Estado de México, Mexico, 453 p. ISBN 968-884-281-8. Hardback. \$60 (Limited numbers are available through the U.S. Forest Service).

*Insectos Forestales de México/ Forest Insects of Mexico* by David Cibrian Tovar, J. Tulio Méndez Montiel, Rodolfo Campos Bolaños, Harry O. Yates, III and Jaime Flores Lara (illustrated by L. Arango Caballero) is a bilingual compendium of Mexico's forest insect pests. *Forest Insects of Mexico* is an ambitious work written to serve as a reference for foresters, IPM practitioners and entomologists. It succeeds admirably as an applied reference text. It covers important forest insects from throughout Mexico's nine diverse forest ecosystems. Introductory sections explain the text's purpose as an IPM tool, describe each forest ecosystem, and provide 29 pages of basic insect taxonomy overviewing the insect orders and families covered in the text. The bulk of the text is divided into insect damage categories that group pest insects according to the tree structures or the timber products damaged. This reference is in many ways similar to the excellent applied reference *Insects That Feed on Trees and Shrubs* by Warren Johnson and Howard Lyon (1976. Cornell Univ. Press). *Forest Insects of Mexico* is lavishly illustrated with 175 color plates, most of which have five to six separate images. In addition, there are 17 original full color life cycle drawings. The text also makes good use of black and white line drawings for simple, field-oriented keys. The authors conveniently present generic information for each pest or pest complex across the top of the page. This section provides scientific name(s), cites pertinent literature, lists host trees, and notes geographic distribution. A map highlighting pest distribution over a Mexican state map would have made that information easier to use. A two column format (Spanish-left side/ English-right side) presents text covering pest descriptions, life cycle and habits, damage, importance and management options. In an appropriate departure from the norm, the final species presented is an eagerly-anticipated winter resident, the monarch butterfly. The biology and life cycle of this much loved overwintering visitor to the fir forests in the states of Michoacan and Mexico is covered in this section. *Forest Insects of Mexico* is a well-organized, applied reference that has an abundance of quality color photography. It is an excellent work that deserves a place in the library of foresters and entomologists.

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## COMMENTS ON BOOK REVIEW

A kind notice of the book, "Beetles of Northeastern North America" (BONENA) reviewed by J. Howard Frank, appeared in volume 79 p. 471-473. A few statements were made, however, that are generally misunderstood. I am pleased to have the opportunity to make the following comments because I believe there is a general misconception about these topics.

## Copyrights

All literary work is now copyrighted in the United States, United Kingdom, and all countries recognizing the International Copyright Laws. It makes no difference whether this is or is not so stated in the work. If you plagiarize someone else's literary work, you are subject to possible lawsuit. The same holds true if you copy (=print) someone else's work and offer it for sale. Printing can be done by photocopy or by any mean of duplication. Therefore, all books, journal articles, booklets, class materials, etc., are "copy righted" whether or not so stated on the publication. There is no way not to copyright such a document. If you register your copyright with the Library of Congress, all you do is receive a certificate that establishes the date your work was published. What does this do? If someone "copies" your work as is, and you can prove that, by their so doing, your means of livelihood was infringed on, you have a case for regaining your losses, if a court so rules. It means nothing else! Please note statement on the copyright page of BONENA: "It should be understood that scientific data contained in this publication are not covered by this copyright and remain public property." This is true, of course, whether or not such a statement is made.

I do have plans for future editions of my several books. This is provided for by a separate corporation known as "The American Insects Project, Inc." The reviewer, Dr. Frank, is a board member of that project. Revisions will be made by new sponsors and revisors under the control of AIP, thus providing for the continuation of these works.

## Illustrations

Originally, Downie and I planned to include about 4,000 illustrations in the work. That was before we really knew how large such a work would be. I wrote to many authors and publishers for the use of drawings. Most wanted anywhere from \$45.00 each up to \$175.00 each for their use. We used many illustrations whose owners did not wish for these fees. This included state and federal publications, with or without copyright statements. However, we realized that many hundreds of these would be figures of male genitalia, and hundreds of these would be tiny, 1-2 mm structures. Our pre-publication sales indicated that the book was of interest primarily to non-specialists, ecologists, or general collectors, those who would not bother to make genitalia dissections. Instead, they would either go to the special literature cited in the bibliography, or to a specialist for help. By eliminating these descriptions, characters in keys, and illustrations, we saved hundreds of pages and many dollars in costs for the consumer.

## Identifications

Many persons wishing to make insect identifications rely on habitus illustrations and make "guessifications." This is so easy; no knowledge of key characters is needed; no need to read lengthy, detailed descriptions; if it looks like it, it must be it. Many serious identifiers can use keys, do read descriptions, and do recognize what can be iden-

tified with a general work such as BONENA, and when it is time to turn to monographic works, hundreds are referred to in BONENA. When all else fails, turn to the specialists! Most important, however, is to be able to recognize the ever present limitations of all works designed as identification aids. Picture keys, colored photos, line habitus drawings, and key characters are of limited use. *Caveat emptor!*

Due to Dr. Downie's illness, we hurried up the work, hoping to complete it in time for him to see it. Thus we missed using many illustrations that might otherwise have been available to us. Actually, other than genitalia illustrations, there are relatively few habitus drawings available that were not used. Notable exceptions are Coccinellidae, Cerambycidae, and Hydrophilidae. All of the drawings in Hatch's five volumes are available for use. Few were suitable for BONENA.

Few specialists have purchased this book for the very reasons given above; they have little use for it. As specialists they write the keys and descriptions and don't need this kind of book. Those who do want it, need to make identifications either for their collections, or for ecological use. Even so, only a few sets of the original printing of the book remain for sale.

Incidentally, when "Beetles of the United States" (BOTUS) first came out in loose-leaf, by design, not by mistake as one recent reviewer in this journal alleged, it was too easy to photocopy it. Not many photocopy machines were in use in 1960. When the American Entomological Institute took it over in the 1970s photocopying was widely used. Some people copied the book even though it cost, then, only \$35.00, and when it went out of print, many photocopied editions were sold at high prices. Unauthorized photocopying is a form of thievery, as is shop lifting. Both cause the high price of books and other goods.

#### Copy Editing

BONENA was a very difficult book to edit. Bob Woodruff, Gene Gerberg, my wife, various specialists, and I read and reread it. Randy Lundgren, who, like the reviewer, specializes in Staphylinidae, has since gone over it very carefully. You won't believe this, but nearly 50% of the mistakes he found are in the family Staphylinidae! It was proofread by a professional specializing on Staphylinidae on a World basis. It seems this relatively poorly known family is still a difficult group to study. With the help of the users of this work, I hope to find all of the errors and typos.

#### Corrigenda & Addenda

I plan to publish corrections and additions from time to time in *Insecta Mundi* and also make these available at no cost to those who have purchased the book. Those who bought through dealers may write to the publisher for these.

#### CD-ROM

Many readers may think that a CD-ROM edition costs less to produce than a hard copy edition. Actually, the quotations we received from manufacturers of CD-ROM disks were nearly twice that of our printing bill. CD-ROM master manufacturers don't work for nothing. The same electronic diskettes must be produced (1721 pages of this, plus illustrations, index, etc. takes the same amount of time as the production of camera ready copy, and often more time, depending on the degree of sophistication of the search ability desired, e.g., just by index works, or by host plant, distribution, etc., items not in the index). The production of the CD-ROM master takes the same



amount of time as setting up a press to print from plates. Authors don't like to work for nothing, even if they are expected to do so. (Journal article authors not only work for nothing, but are expected to pay page charges too.) The advent of the personal computer merely transferred "type setting" from the printer to the author. If the author does this for nothing, it is because he is expected to do this as part of the terms of his employment. My experience with such "camera ready copy" for *Insecta Mundi* has shown that it is better to produce a typescript, and leave the typesetting to the few who know how to use typefaces, and make up pages. There is no magical transformation from a diskette sent in by an author, to the printed page produced by the printer (or the CD-ROM producer). Someone who knows how has to do it, and it takes time. The equipment to produce these items is not cheap, and does not exist in the ordinary professor's office. Then there is the problem of the user. Very few of those who own copies of BONENA would find it convenient to use a CD-ROM disk to make identifications of beetles; most do not have the equipment, including Dr. Frank. If you have priced both hard copies of books (various technical publications) that also have CD-ROM editions, you will see that the CD-ROM edition is much more expensive, reflecting the difference in production cost.

#### On-line

Writing articles, guides, and books, and putting the results "on line" for free use is an entirely different matter. This is cheap and convenient for the consumer, at least for those who have computer equipment. It may be done by anyone, with or without peer review; one never knows! However, I believe, since many universities hardly recognize book writing as a step toward tenure, few will bother to use this channel for book production.

Ross H. Arnett, Jr.  
Courtesy Professor  
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EDITED MINUTES OF THE 79TH ANNUAL MEETING,  
FLORIDA ENTOMOLOGICAL SOCIETY

The fourth and final 1995-96 Executive Committee meeting was held at the Sheraton Sand Key Resort, near Clearwater, Florida. President Russ Mizell called the meeting to order at 4:10 PM, on August 5, 1996.

The 1995-96 Annual Business Meeting of the Society was called to order by President Mizell at 5:00 PM, Tuesday, August 6, 1996. A total of 51 Society members were present. Minutes of the 1995 Annual Business Meeting at the Cariari Hotel in San Jose, Costa Rica, were accepted as published in the Florida Entomologist 79(1): 83-89. Final reports from the various standing committees of the Society were presented herein. President Mizell passed the gavel to the new president, Everett Mitchell. No further business was discussed. The meeting adjourned at 6:15 PM.

REPORT OF THE BUSINESS MANAGER  
JANUARY 1, 1995 TO DECEMBER 31, 1996

## INCOME:

Operating Income	
Membership Dues	15,267.50
Subscriptions	5,760.00
Annual Meeting	3,952.39
Miscellaneous	90.56
Entomology Directories	65.00
Promotional Materials (T-shirts, posters)	601.34
Contributions	50.00
Total Operating Income	<u>25,786.79</u>
Other Income Interest Income	<u>3,499.68</u>
Total Income	<u>29,286.47</u>

## EXPENSES

Office Expenses	812.45
Postage	560.19
Contract Labor	12,730.80
Travel	262.95
Contributions	200.00
Grants/Scholarships	1,800.00
Journal Printing	2,767.38
Editing	1,050.07
Newsletter	169.51
Miscellaneous	156.48
Dues and Subscriptions	112.50
Depreciation	430.24

Bank Charges	181.50
Student Activities	1,680.00
Income Tax	363.49
Total Expenses	<u>23,277.56</u>
NET INCOME	<u>6,008.91</u>

## A. C. KNAPP, BUSINESS MANAGER

Ann Knapp has resigned as Business Manager, but will be retained as a consultant to advise the new Business Manager until August 1997. The Executive Committee would like to thank Ann for her many years of service to the Society. The new Business Manager is Teresa DuChene of Lutz, Florida.

FISCAL COMMITTEE REPORT  
1994 AND 1995

The Fiscal Committee examined the record for 1994 and 1995 and found no irregularities in the transactions we examined. Having no training in this area and no procedure to follow, we found the experience somewhat frustrating.

After much discussion with Ann Knapp, the Fiscal Committee recommends the following:

1. That we have an accountant examine the financial records on a yearly basis or have an accountant develop a procedure for the committee to follow. The accountant who has prepared our taxes in the past, R. D. Respass, Newberry, Florida, is willing to audit our financial records on a yearly basis at a rate of \$35 per hour. He estimates that it would take 10 hours. The alternative is to have him outline a procedure for the committee to follow.
2. That we invest the funds in excess of one year's expenses (currently about \$45,000) in certificates of deposit of staggered maturities. Ann Knapp recommends one-third in a 3-month CD, one-third in a 6-month CD, and one-third in a 12-month CD, as interest rates may go up. The fiscal committee would then make recommendations for changes as the CDs mature. All investments of the society's funds should be without risk, even though this means lower interest rates.
3. That we seriously consider offering the membership the convenience of using MasterCard or Visa to pay dues and meeting registration. This would be especially helpful to members who do not live in the United States. Ann Knapp has provided information from several banks. Options were estimated based on all 475 members paying their dues by credit card, 100 meeting registrations, and a monthly service charge in lieu of purchasing the electronic authorization machine. There are also 200 additional subscriptions to the journal. This a total 775 transactions per year for a total of approximately \$25,000. Although initial costs are high, the cost becomes more reasonable if we buy the machine, and if (as is likely) half or fewer of the members use credit cards to pay their dues and meeting registration fees.
4. That, on the advice of Ann Knapp, we switch to First Union Bank, which has an interest-bearing checking account, similar to Merrill Lynch, and a savings account, which Merrill Lynch does not. We could also have our CDs there. We may get a better deal on Visa/MaterCard fees if we do all our banking with them. This bank has many branches throughout Florida.

Finally, we are sorry that Ann Knapp has decided to resign. The Committee is glad that she was still the Business Manager. But now that she is leaving, we suggest that the Executive Committee consider splitting the duties of receiving and disbursing funds. The person who deposits funds could send the deposit slip and a record of the source of the funds to the Business Manager, who would continue to do the rest of the Society's business.

S. WEBB, CHAIR

REPORT OF THE PROGRAM COMMITTEE

A total of 77 oral presentations, including symposia and special reports on 'FES and the Internet', and 5 poster displays were scheduled for the 79th Annual Meeting. Three oral presentations were canceled; but replacements were secured for two slots for a net total of 76 oral presentations. A total of four symposia and one workshop also were scheduled.

*Discussion:* E. Thoms mentioned that FES should draw up guidelines for symposium organizers to specify how they may use the funds for symposium expenses.

REPORT OF THE HONORS AND AWARDS COMMITTEE

At its 79th Annual Meeting, the Florida Entomological Society recognized five individuals for achievements in entomology:

Annual Achievement Award for Teaching (K-12)

Laura P. Bridgewater

Annual Achievement Award for Teaching (Higher Education)

Bill Howard

Annual Achievement Award for Research

Ray Yokomi

Annual Achievement Award for Industry

Joe Eger

Entomologist-of-the-Year

Russ Mizell

Plaques were presented to Russ Mizell and Ellen Thoms for their dedicated service as past presidents of the Florida Entomological Society. Other individuals receiving plaques for service were Fred Petitt, Secretary of the Florida Entomological Society, Cliff Lofgren, Editor of the Florida Entomologist, and Ann Knapp, Business Manager of the Florida Entomological Society.

Certificates of appreciation were presented to Stephen Bambara, Sudhir Narang and Geoffrey Zehnder, for service as Associate Editors of the Florida Entomologist. Joe Eger, Gary Liebee and Moh Ling Kok-Yokomi received certificates of appreciation for service on special committees.

R. K. SPRENKEL, CHAIR

REPORT OF THE STUDENT ACTIVITIES COMMITTEE

The committee made a concerted effort this year to encourage student participation in the various FES student activities. We made a presentation to the University of

Florida Entomology Student Organization to outline FES scholarships, mini-grants, travel funds, and the student paper contest. Feedback from students indicated that they would like to be given the judging forms for the student paper contest to see where they need to improve. This will be done following this year's annual meeting. Students also asked for guidelines for scholarships. There are no current guidelines so the committee made an effort to develop them. The consensus of the committee was that a point system similar to that used in the student paper contest should not be used. Rather, a list of criteria used to judge scholarships was developed without attaching points to each of the criteria. A copy of this list is included with this report and should, in the future, serve as a guideline for students preparing scholarship applications.

Participation in student activities was excellent this year. Eleven students entered the student paper contest. There were 13 applicants for scholarships, 15 applicants for mini-grants, and five requests for student travel aid. Recipients of the three scholarships were: Wendy L. Meyer, Dini M. Miller, and Juan Villanueva-Jimenez. Students receiving mini-grants were: Julieta Brambila, Wayne T. Grush, Denise L. Johanowicz, Jaw-Ching Liu, Dini M. Miller, Andrew K. Rasmussen, Dina Richman, Marco A. Toapanta, Kevina Vulinec, and John Petti. Student travel funds in the amount of \$160.00 were awarded to each of the following: Julieta Brambila, Rejane Rocha de Moraes, Dina Richman, Tonya Van Hook, and Kevina Vulinec. The student paper contest awards went to: Robin Goodson, first place; Denise Johanowicz, second place; and Dini Miller, third place.

The committee would like to thank Dini Miller, president of ENSO, for organizing the meeting we had with students, and Phil Stansly and David Hall for assistance in judging the student paper contest.

#### CRITERIA EVALUATED FOR JUDGING STUDENT SCHOLARSHIP APPLICANTS

##### INFORMATION TO INCLUDE IN CV:

- Refereed Publications
- Non-Refereed Publications
- Papers Presented at Entomology Meetings
- Papers Presented at Other Professional Meetings
- Symposia/Workshop Presentations
- Outreach Activities and Presentations
- Honors and Awards
- Grants
- Service in Professional Societies
- International Activities

##### OTHER REQUIREMENTS

- Grades (Transcripts)
- Letters of Recommendation for this Award
- Statement of Future Plans

J. EGER, CHAIR

#### REPORT OF THE SUSTAINING MEMBERSHIP COMMITTEE

The committee is pleased to report that we have two new members: Dr. Clair Erickson of Monsanto and Dr. J. Scott Ferguson of the Ciba Corporation.

The committee also sent out letters to over 50 FES members soliciting financial support for student travel and industry sponsored events for the annual meeting. A total of \$2200 was contributed by 18 members, \$800 for student travel and \$1400 for industry sponsored events. Student travel was sponsored by: A. Duda & Sons, Inc.; Ag Bio Enterprises, Inc.; All America Termite & Pest Control; DowElanco; E.I. DuPont de Nemours & Co.; Florida Fruit & Vegetable Association; Florida Sugar Cane League; Sandoz Crop Protection Corporation; Zellwin Farms Company; and Zeneca Inc. The FES Mixer was sponsored by: All America Termite & Pest Control; American Cyanamid Company; DowElanco; E.I. DuPont de Nemours & Co.; E.O. Painter Printing Company; Florahome Pest Control Inc.; Florida Fruit & Vegetable Association; Helena Chemical Company; McLaughlin Gormley King Company; Sandoz Crop Protection Corporation; Uniroyal Chemical; and Zeneca Inc. Many thanks to all the sponsors!

K. R. MUZYK, CHAIR

REPORT OF THE MEMBERSHIP COMMITTEE

The Florida Entomological Society currently has 411 full members, 47 sustaining members, 55 student members, 10 emeritus members, and 9 honorary members. During 1996, the membership committee contacted about 70 members that were delinquent in paying dues. Of these members, about 20% renewed their membership. In addition, in 1996 there were 26 new full memberships and 18 student memberships.

P. KOEHLER, CHAIR

REPORT OF THE PUBLICATIONS COMMITTEE

A total of 642 pages were published in Volume 78 (1995) including: Two symposiums with a total of 11 papers, 45 research reports, 22 scientific notes, 5 book reviews, one bibliography, one In Memorium, the Minutes of the 1994 Annual Meeting, and one erratum.

Seventy-one research reports and scientific notes were received for publication in 1995: 48 have been published, 10 rejected and 13 remain in the peer review process.

Thus far in 1996, 52 research reports and scientific notes have been received: 12 have been accepted for publication. Two papers in Spanish have been returned to the authors for English translation.

Four Associate Editors have resigned, or will resign, before the end of 1996. They are Drs. Greg Wheeler, S. K. Narang, Steve Bambara and Geoffrey Zehnder. Four new Associate Editors have been appointed. They are Drs. John Capinera, Charlie Morris, Guy Hallman and Alan Bartlett.

Publication costs for the *Florida Entomologist* have not increased over the past 4 years. An overview of data supplied by the E. O. Painter Printing Company indicates that income from page charges has exceeded publication costs in all except one issue.

This is my last year as Editor of the *Florida Entomologist*. It has been an interesting and challenging 4 years, and I have enjoyed my association with Associate Editors and authors alike.

Discussion: C. Lofgren pointed out that this is the 79th Volume of the Florida Entomologist and that is a record of which the Society can be very proud.

D. Hall moved and E. Thoms seconded the motion that FES appoint Richard Baranowski as Editor. Motion carried.

C. LOFGREN, EDITOR

## REPORT OF THE NOMINATING COMMITTEE

Forty-eight ballots were received and counted by Ellen Thoms. There was a tie for Vice President. It was determined that Joe Funderburk will be Vice President for 1997 and John Sivinski for 1998. Harold Browning and Brett Highland were nominated for Member-At-Large. H. Browning won. Mary Jo Hayes was elected secretary.

E. THOMS, CHAIR

## REPORT OF THE EDUCATION COMMITTEE

The Society participated in the State Fair with an exhibit entitled "Insect Encounters". It was a huge success with over 100,000 visitors to the exhibit. An undertaking of this kind will require more volunteers if it is to be a success next year.

FES sends judges to the Annual State Science and Engineering Fair to choose a senior section and junior section student with outstanding projects in entomology. The award includes \$100, a certificate, and a chance to attend our annual meeting. This year's winners are:

Justin Lee Coffee, Indian Harbor Beach: "Using Poisonous Plants as Safer, Effective, and More Cost Efficient Pesticides"

Casey R. Spindler, Hollywood: "A Study of Bio-Rational, User-Friendly Pesticides on Crickets"

M. J. HAYES, CHAIR

## REPORT OF THE CARIBBEAN DIRECTORY COMMITTEE

The committee maintains a computerized database of entomologists in the Caribbean region. An alphabetical directory, prepared from the database, was published on paper by FES in 1994. Since then, the database has been maintained by incorporating mailed-in additions and corrections, and by building an alphabetical list of acronyms.

Two correspondents have suggested a second printed edition of the directory in which entries (names of entomologists) would be listed by country instead of alphabetically regardless of country. The committee will follow directions from FES in this matter.

The committee points out that the computerized database is thoroughly searchable electronically for many kinds of information, so that there are very many possibilities for arrangement of a printed edition. The committee believes that the best approach will be to place the directory on the World Wide Web, linked to the forthcoming FES home page. However, it seems that software still is not available to take advantage of the searchability of the information. In other words, placement of the directory on the World Wide Web should be delayed until software can be obtained to make customized searches to provide listings. For example: (1) all entomologists resident in Caracas, (2) all entomologists interested in sugarcane entomology, (3) all members of sociedad Venezolana de Entomologia, (4) all entomologists employed by Universidad Nacional Autonoma de Mexico, (5) the telephone and fax numbers of Costa Rica 18 Instituto Nacional de Biodiversidad, etc.

J. H. FRANK, CHAIR

## REPORT OF THE 1997 MEETING SITE SELECTION COMMITTEE

The Eightieth Annual Meeting of the Florida Entomological Society will be held from August 4-7, 1997, at the Adams Mark Hotel in Daytona Beach, Florida.

HONORARY MEMBERS OF THE FLORIDA ENTOMOLOGICAL SOCIETY,  
1995-96

H. A. Denmark  
W. G. Eden  
E. Gerberg  
L. A. Hetrick  
L. C. Kuitert  
F. Mead  
A. J. Rogers  
A. G. Selhime  
H. V. Weems

NECROLOGY

George B. Craig Jr.  
Carl E. Stegmaier  
George C. Steyskal  
Daniel O. Wolfenbarger

S. BRODA-HYDORN, CHAIR

EXECUTIVE COMMITTEE MEETINGS  
1995-1996

09 November 1995, Gainesville  
11 January 1996, Lake Alfred  
21 March 1996, Gainesville  
23 May 1996, Lake Alfred  
05 August 1996, Clearwater Beach

These minutes of the 79th Annual Meeting of the Florida Entomological Society were reviewed by the 1996-97 Executive Committee in January 1997.

FRED PETITT, SECRETARY



PHOTOGRAPHS FROM THE 79TH ANNUAL  
FLORIDA ENTOMOLOGICAL SOCIETY MEETING,  
AUGUST 1996

1



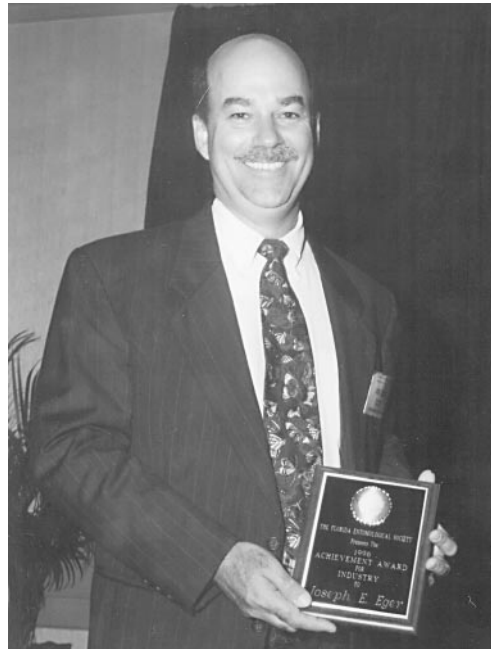
2



Fig. 1. Ray Yokomi (left) receives the Annual Achievement Award for Research from Richard Sprenkel (right) and President Everett Mitchell.

Fig. 2. The Annual Achievement Award for Teaching is presented to Bill Howard.

3



4



Fig. 3. Joe Eger was honored with the Annual Achievement Award for Industry.  
Fig. 4. Joe Eger (far left) and Everett Mitchell (far right) with Student Paper Contest award winners Denise Johanowicz (second from left; Second Place), Robin Goodson (First Place), and Dini Miller (Third Place).



Fig. 5. Dini Miller receives a Florida Entomological Society Scholarship presented by Everett Mitchell and Joe Eger.

Fig. 6. President Everett Mitchell presents a Dedicated Service Award to Cliff Lofgren who served the Society as Editor of the *Florida Entomologist* from 1993 to 1996.

Fig. 7. Ann Knapp receives a Dedicated Service Award for serving the Society as Business Manager from 1983 to 1996.