(ISSN 0015-4040)

FLORIDA ENTOMOLOGIST

(An International Journal for the Americas)

Volume 68, No. 2 *June, 1985*

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Published by The Florida Entomological Society

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Manuscripts and other editorial matter should be sent to the Editor, JOHN R. MCLAUGHLIN, 4628 NW 40th Street, Gainesville, FL, 32606.

This issue mailed June 10, 1985

68th ANNUAL MEETING—FLORIDA ENTOMOLOGICAL SOCIETY

1. *DATE AND LOCALE*: August 5-8, 1985; Ocho Rios Sheraton Hotel; Ocho Rios, Jamaica, West Indies.
2. *OFFICIAL TRAVEL AGENCY*: EMMER TRAVEL, INC., 2801 S.W. Archer Road, Gainesville, FL 32608; contact Ms. Lona Stein at (904) 377-1222 (Gainesville residents) or (800) 342-2223 (toll free for Florida residents) or (800) 874-8487 (toll free for USA residents).
3. Refer to the December 1984 issue of **FLORIDA ENTOMOLOGIST for details. Contact Carl Barfield (904-392-7089) or Dave Schuster (813-755-1568) if you have questions.**

10TH CONGRESS OF BRAZILIAN ENTOMOLOGY

The 9th Congress of Brazilian Entomology was held in Londrina, Parana in July 1984 with more than 600 participants. It was a very special meeting with round tables, feature speakers, panels, hundreds of research papers covering all aspects of Entomology. There was great interest in the competition of papers presented by graduate students.

The newly elected President is Jocelia Grazia, researcher from the Federal University of Rio Grande do Sul, Porto Alegre; Vice-President is Euripedes B. deMenezes; both well known in international circles.

The next Congress will be held in Rio de Janeiro 26-31 of January in 1986 in the Hotel Gloria. Plan to attend. For more information on membership and future meetings, write to:

Sociedade Entomologicaide Brasil
A/C Ruth H. Mocellin
Depto. de Zoologia—UFRGS
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BRASIL

Student Scholarship Grants

The Florida Entomological Society will award three $500.00 scholarship grants to students majoring in entomology. The criteria for selecting the awardees are:

1. The student must be a member of the Florida Entomological Society.
2. The quality of scholarship reflected in students transcript.
3. Letters of recommendation from two faculty members.
4. Curriculum vitae of the student.
5. A statement from the student about his or her future plans in the field of entomology.
6. The candidate must be a full time student with at least one year remaining in his or her degree program.

Application packages must be mailed to D. L. Shankland, Deperatment of Entomology and Nematology, University of Florida, Gainesville, FL 32611 on or before July 1, 1985.

RECRUITMENT OF THE RED IMPORTED FIRE ANT, *SOLENOPSIS INVICTA*, TO SOYBEAN OIL BAITS

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ABSTRACT

A field investigation was conducted to compare the diel periodicity and rates of recruitment of the red imported fire ant, *Solenopsis invicta* Buren, to soybean oil presented in two forms. Bimodal patterns of recruitment were usually observed to corn cob particulates saturated with oil but not to cotton wicks saturated with oil. Recruitment to both rates was usually higher at night but not always significantly ($P \geq 0.05$) different from rates observed during the day. Significantly ($P \leq 0.05$) higher rates of recruitment occurred to the particulate oil bait relative to the liquid oil bait at most times studied. The size of ants recruited to the two baits varied significantly ($P \leq 0.05$); however, no consistent or explainable pattern in the size of ants recruited over each 24-hour period was observed for either bait. Ants of the media worker subcaste were generally recruited at significantly ($P \leq 0.05$) greater rates to both baits relative to minor and major workers. Standard multiple regression analyses revealed that changes in air and soil temperatures had a significant ($P \leq 0.05$) impact on recruitment; however, changes in air and soil moisture did not appear to influence rates of recruitment to the baits.

RESUMEN

Se condujo una investigacion en el campo para comparar la periocidad "diel" y los grados de obtener aceite de soya presentado en dos formas por la hormiga roja importada, *Solenopsis invicta* Buren. Se observó un patrón bi-modelo en la obtención de partículas de mazorca de maíz saturadas en aceite pero no en mechas de algodón saturadas en aceite. La obtención a ambos niveles usualmente fue más alta de noche, pero no siempre significativamente diferente ($P \geq 0.05$) de los grados observados durante el dia. La mayoría de las veces que se estudió, se obtuvo significantemente ($P \leq 0.05$) grados más alto de obtención ocurrido con trampas de cebo con partículas de aceite relativo a cebos de aceite líquido. El tamaño de las hormigas obtenidas en las dos trampas varió significantemente ($P \leq 0.05$), sin embargo no se observó un patrón explicable o consistente en el tamaño de las hormigas obtenidas durante un período de 24 horas en ninguna de las trampas. Hormigas trabajadoras de la sub-casta media fueron generalmente obtenidas en grados significantemente ($P \leq 0.05$) más altos relativo a trabajadoras menores y mayores hacia ambos cebos. La norma del análisis de regresión multiple reveló que cambios de temperatura en el aire y en la tierra tuvieron un impacto significante ($P \leq 0.05$) en lo obtención, sin em-

bargo, cambio en la humedad aire y de la tierra aparentemente no influyeron los grados de obtención de las trampas.

Introduction

The red imported fire ant, *Solenopsis invicta* Buren, has spread throughout a large portion of the Southeast after being introduced into the United States from South America (Lofgren et al. 1975). *S. invicta* is a highly territorial species (Wilson et al. 1971) that is characterized by the large size of its colonies (Lofgren et al. 1975) and the mass recruitment of worker ants to food sources (Wilson 1962). Efforts to control *S. invicta* populations have traditionally involved the use of soybean oil-insecticide mixtures impregnated on corn cob particles (Lofgren et al. 1975). Foraging workers retrieve particles that have been broadcast over infested areas or spread around the perimeter of *S. invicta* colonies. Since some currently used toxic baits are rapidly degraded (Apperson et al. 1984, Vander Meer et al. 1982), knowledge of recruitment activities would help to improve the timing of bait applications and thereby improve the efficiency of control programs.

The objectives of our investigation were: (1) to compare recruitment over a 24-hour period to two forms of soybean oil baits; and (2) to determine the impact of some meteorological and edaphic factors on *S. invicta* recruitment activities.

Methods and Materials

Experiments were conducted in a 6.1-ha field near Bolivia, Brunswick County, North Carolina, between May and July 1982, prior to the planting of soybeans (*Glycine max* (L.) Merr.). The field had been disked in the fall of 1981, and some weeds, primarily sicklepod (*Cassia obtusifolia* L.), Pennsylvania smartweed (*Polygonum pensylvanicum* L.), and morning glory (*Ipomea* spp.) were found across the field.

Baits

Once-refined soybean oil was used as bait. Soybean oil was chosen as a stationary, concentrated food source because it is readily accepted by *S. invicta* (Hays and Arant 1960, Lofgren et al. 1964) and is easily distributed on a particulate carrier (Lofgren et al. 1973). Once-refined soybean oil was presented in two forms: on a corncob grit carrier; and in one dram vials fitted with cotton wicks. The particulate bait was placed in a pile on a flat plastic dish 15 cm in diameter. The liquid bait was contained in 12 vials arranged in a circle and inserted horizontally to ca. one-half their length into holes punched near the bottom of a plastic container. This container was pushed down into the soil so that the wicks contacted the soil surface. These two bait stations were left in place throughout each 24-hour observation period.

Experimental Area and Placement of Baits

Sampling was carried out near two *S. invicta* mounds which were located adjacent to pine woods at the periphery of the field. The mounds were of

similar size (ca. 0.6 x 0.4 x 0.3 m high) and were ca. 115 m apart. A particulate oil bait was placed ca. 6 m away from one mound and a liquid oil bait was placed ca. 6 m from the other mound. On each successive sampling date, the bait stations were switched to the opposite mounds to preclude effects of hunger state, food preference or colony size upon recruitment rates. The liquid and particulate baits were placed in the field one hour before observations were initiated to allow ants to locate the baits and establish recruitment trails.

Observations

At the recruitment trail established to each bait station, a string was tied across the trail between two stakes about 1 m from each bait. Ants moving past this point, traveling toward the bait, were counted. Because the ant trail was usually disrupted by the approach of an observer, it was necessary to wait several minutes until regular traffic flow resumed before observations were made. Once the flow resumed, all ants passing under the string on their way to the bait were counted for 2 minutes. Counts were made every 4 hours, with a total of 7 counts made for each 24-hour period. A headlamp was used to make observations at night. A diel sampling was carried out on 5 dates. Observations for the first sampling date (May 27) were initiated at 0900 hrs, the second (June 2) at 1400 hrs, and third (June 15), fourth (June 28), and fifth (July 2) at 1600 hrs.

Some of the ants running on the recruitment trails were collected with an aspirator during each observation. These ants were brought back to the laboratory and their head capsule widths were measured to determine if there were any changes in the size of workers recruited to the baits over time. Voucher specimens of fire ants have been deposited in the Entomology Museum of North Carolina State University.

Abiotic and Edaphic Parameters

Measurements of air and soil temperature, relative humidity, and soil moisture for correlation with fire ant recruitment activities were taken following each observation period. Temperatures were measured with an Extech® Model 1200 digital thermometer, and all readings were taken close to the recruitment trail without disturbing the ants. Air temperature was measured ca. 3 cm above the soil surface and soil temperature was measured after pushing the probe just under the surface. A Bacharach® sling psychrometer was used to measure relative humidity. For moisture determinations, shallow soil samples were taken with a Hoffer sampler. The samples were weighed in the field immediately after collection to the nearest 0.1 g and then brought back to the laboratory and dried in an oven to a constant weight. Values for soil moisture were calculated on a percent dry weight basis. Temperature, soil moisture and relative humidity data were collected at each bait station.

Statistical Analyses

A contingency table was constructed for the numbers of ants counted running toward the 2 baits at the 7 time intervals on each and over all sampling dates. Chi-square tests were carried out to determine if the re-

cruitment rates to the baits varied independently and also to test the hypothesis of equal recruitment for the two baits at a given date. The partitioning of the chi-square for bait x date x time was accomplished by the FUNCAT procedure of the Statistical Analysis System (Helwig and Council 1979). Standard multiple regression procedures were used to determine effects of the temperature and moisture variables on recruitment rates to the baits.

Measurements of *S. invicta* head capsule width were grouped according to the worker subcaste classification of Wilson (1978). Chi-square tests were carried out to determine if the numbers of ants of each subcaste recruited to the two baits varied independently. Unless otherwise indicated, all statistical analyses were performed at the $P \leq 0.05$ level of significance.

Results and Discussion

Periodicity of Recruitment

Recruitment to the particulate bait exhibited a bimodal pattern on 4 of the 5 sampling dates (Fig. 1). When trials were initiated in the late afternoon, recruitment activity was observed to peak at night and again the following day. The opposite situation occurred when the trials were started in the morning or early afternoon. A bimodal pattern of recruitment to the liquid bait generally was not found. Movement of ants along the

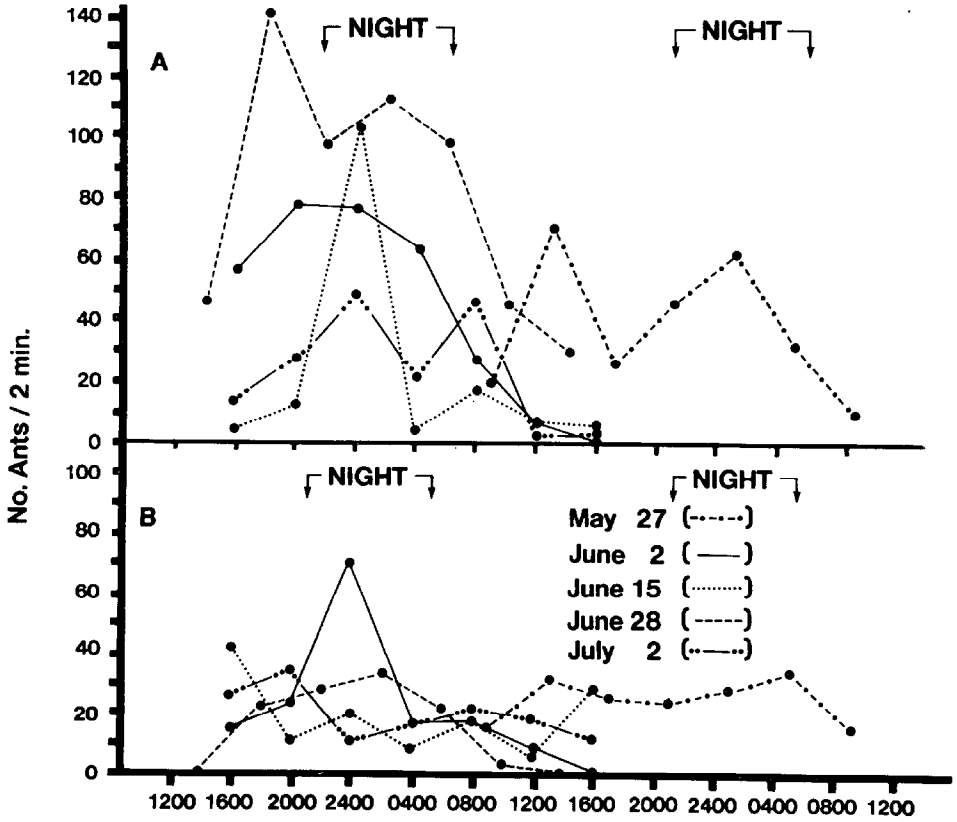

Fig. 1. Diel recruitment of *S. invicta* to particulate (A) and liquid (B) soybean oil baits.

recruitment trails decreased at the end of the 24-hour observation periods, sometimes ceasing altogether regardless of when the trials were initiated. Recruitment to both baits was usually higher at night but not always significantly different from rates observed during the day.

Rates of Recruitment to Liquid and Particulite Oil Baits

Movement of *S. invicta* to the liquid bait was slower than to the particulate bait, and the differences were highly significant ($P \leq 0.01$) (Table 1). The hypothesis of equal recruitment between the two baits was rejected for all but one of the dates studied (Table 2). There are several plausible explanations for observed differences in recruitment to the two baits. A time factor may be involved. Ants had to stay at the vials to drink from the wicks which required more time than transporting an individual bait particle to the nest. Taylor (1978) recognized time spent drinking as an important variable in his model of recruitment rates of *Solenopsis geminata* (F.). The surface area of a food source is another important determinant of recruitment; Wilson (1962) and Taylor (1977) showed that the number of worker ants at a food mass is related to the surface area of the food mass. In our investigation, the particulate bait provided a larger surface area relative to the liquid bait; however, differences in the surface area

TABLE 1. Comparison of the rates of recruitment of *S. invicta* worker ants to particulate and liquid soybean oil baits.

Date	Chi-square[a]	Prob. > chi-square
May 27	15.63	0.008
June 2	24.64	0.0001
June 15	104.18	0.0001
June 28	39.84	0.0001
July 2	32.22	0.0001
Over all dates	97.36	0.0001

[a]Each chi-square value reported is from a 7 X 2 (Time of Day) X (Bait) contingency table and is based on 6 degrees of freedom.

TABLE 2. Comparison of total numbers of *S. invicta* workers recruited to particulate and liquid soybean oil baits.

Date	Particulate bait	Liquid bait	Chi-square[a]	Prob. > chi-square
May 27	280	188	18.08	<0.005
June 2	591	114	269.60	<0.005
June 15	159	143	0.84	>0.10
June 28	315	186	33.22	<0.005
July 2	173	119	9.99	<0.005
Over all dates	1518	750	260.06	<0.005

[a]The chi-squares (df = 1) test the null hypothesis of equal recruitment between the two baits. Significance of chi-square implies unequal recruitment for the two baits.

of the baits does not appear to be an important factor. Workers crowded around individual wicks at the liquid bait, but all of the wicks were never fully occupied by ants. Other factors known to affect recruitment, such as colony size and size-age composition of workers (Sorensen et al. 1981), hunger state (Howard and Tschinkel 1982) and food preferences (Glunn et al. 1981), should have been of no consequence since the two types of soybean oil baits were alternated between the *S. invicta* colonies used. Quality of food could also influence the number of workers recruited to a food source. Hangartner (1969) and Taylor (1977) found *S. geminata* to recruit at greater rates when the concentration of sucrose solutions was increased. Presumably, in our experiment, oil in liquid form would provide a more concentrated, accessible food source (of higher quality) that could be easily spread through the colony through trophallaxis. However, after a more careful examination, the resource values of a worker-load of food (Carroll and Janzen 1973) for the particulate oil bait appear to be greater. We calculate that bait particles contained ca. 30 μg of oil since each particle weighs an average of 0.2 mg and can absorb 15% of its weight in oil (Lofgren et al. 1973). Because only 50% of the oil can be extracted from the particulate bait (Banks et al. 1973), each worker-load of food is equivalent to ca. 15 μg of oil. Sorensen et al. (1981) determined that on the average each *S. invicta* forager ingests 6.57 μg of oil from liquid baits. The two values are sufficiently different to suggest that *S. invicta* may recruit at higher rates to the particulate bait because each particle contains more oil than a worker can consume. Additionally, the storage properties of the two kinds of bait are quite dissimilar. Particulate bait could be easily stored inside the nest and the oil consumed as needed; however, liquid bait would have to be fed immediately to nest mates or retained (in a replete caste). While there is evidence that both of these activities do occur in *S. invicta* colonies, it would seem more likely that *S. invicta* colonies would have a greater capacity in the short term to store particulate bait and for this reason, they recruit to it at higher rates. Certainly more carefully controlled experiments must be carried out to confirm this hypothesis.

Recruitment of Subcastes

Mirenda and Vinson (1981) and Wilson (1978) found that *S. invicta* exhibits a weak polymorphism that is somewhat reflected in task specialization. Small (minor) workers were more likely to care for brood while large (media and major) workers foraged and defended the nest. Wilson (1978) correlated worker size with the size of particles transported. Small workers carried particles of all sizes while larger workers tended to carry only the larger particles. Mirenda and Vinson (1981) showed that media and major foragers were more likely to retrieve solid insect prey than were minor workers. Sorensen and Vinson (1981) reported differences in the size classes or workers recruited to various kinds of food. Smaller numbers of workers of all size classes were recruited to honey, but more media and major workers were found when insects were presented as food. Howard and Tschinkel (1981) found that on an ant-weight basis, foragers of all size classes ingested similar quantities of oil. We found no evidence to suggest that the form in which the oil was presented altered the size of ants recruited. Our analysis of the numbers of ants of each *S. invicta* subcaste recruited indicated that there were no significant differences between the

two baits for the time periods within each sampling date (Table 3). No consistent or biologically rational trend of increase or decrease in the proportion of each subcaste recruited over each 24-hour sampling for each bait was found when the data were examined. While the numbers of each subcaste recruited to the 2 baits on each sampling date were found to vary independently (Table 3), no consistent pattern of difference between the baits was found. We did find that significantly greater numbers of media workers were recruited to the baits relative to minor or major workers. In this regard, our results are consistent with those reported by Mirenda and Vinson (1981). They showed that media workers were more likely to forage relative to minor and major workers.

Impact of Environmental Factors on Recruitment

Attempts to determine the impact of environmental parameters on recruitment yielded models that contained quadratic and interaction forms of the time, temperature and moisture variables measured. Recruitment to the baits did not show a strictly linear relationship with any of these parameters. While air and soil temperatures did have a significant influence on recruitment rates, the proportion of the total variation in recruitment explained by these parameters was small (<25%). Air and soil moisture did not appear to have a significant impact on recruitment to the baits.

Rhoades and Davis (1967) reported that the optimum range of air temperature for *S. invicta* foraging activity is 21°C to 29°C with soil surface temperatures below 35°C. During our investigation, temperatures rarely exceeded these optimum ranges. Air temperature declined below the optimum range found by Rhoades and Davis once during our investigation, but this did not have an adverse effect on recruitment. Because low temperatures generally occurred at night, the observed recruitment patterns could not be attributed solely to temperature. It is possible that high humidity and darkness affected *S. invicta* recruitment activity. Recruitment to oil baits continued throughout the night, usually showing a peak of activity during the dark hours (Fig. 1). Recruitment to the liquid and particulate baits was inhibited more by high temperatures at the end of the 24-hour

TABLE 3. Analysis of the recruitment of *S. invicta* worker subcastes to particulate and liquid soybean oil baits.

Parameter	df[a]	Chi-square[b]	Prob. > chi-square
Intercept	2	4.13	0.127
Bait	2	0.50	0.779
Date	8	14.58	0.0677
Bait X date	8	57.70	0.0001
Bait X time	12	8.93	0.7091
Date X time	48	59.14	0.130
Bait X date X time	44[c]	48.60	0.293

[a]Degrees of freedom for intercept and Bait and Date main effects reflect the fact that separate intercepts have been fitted for each bait.
[b]The total chi-square for bait X date X time was partitioned by the FUNCAT procedure.
[c]Degrees of freedom reflect missing data.

period than at the beginning of the period regardless of when the trials were initiated. This observation suggests that *S. invicta* will recruit to concentrated food sources during unfavorable environmental conditions until the hunger state of the colony is satiated.

ENDNOTES

This is paper no. 8949 of the Journal Series of the N. C. Agric. Res. Serv., Raleigh.

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A SLAVE-MAKING ANT IN FLORIDA: *POLYERGUS LUCIDUS* WITH OBSERVATIONS ON THE NATURAL HISTORY OF ITS HOST *FORMICA ARCHBOLDI* (HYMENOPTERA: FORMICIDAE)

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ABSTRACT

The slave-making ant *Polyergus lucidus* is reported for the 1st time from Florida. *Formica archboldi* is its host species, not previously known to be parasitized in this way. The behavior of these 2 species is described and compared to that of related forms from other regions.

RESUMEN

Se registra por primera vez la hormiga esclavista *Polyergus lucidus* de la Florida. *Formica archboldi* es su hospedero, que no se conocía previamente que era parasitado de esta forma. Se describe el comportamiento de las 2 especies, y se compara con el de hormigas emparentadas de otras regiones.

Dulosis is a form of social parasitism in which the workers of 1 species of ant periodically raid colonies of related species for brood. The plundered brood is reared in the nest of the parasite by workers of the host species which serve as the nurse, forager, defense, and construction force for the mixed colony. Often referred to as slave-making, this type of parasitism is unique to Formicidae, but has arisen several times independently within the family (Wilson 1971).

Talbot (1967, 1968), Harman (1968) and Marlin (1968, 1969, 1971) have reported on the natural history of *Polyergus lucidus* Mayr in Michigan and Illinois, and Kwait and Topoff (1983) have recently published on the species'

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A SLAVE-MAKING ANT IN FLORIDA: *POLYERGUS LUCIDUS* WITH OBSERVATIONS ON THE NATURAL HISTORY OF ITS HOST *FORMICA ARCHBOLDI* (HYMENOPTERA: FORMICIDAE)

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ABSTRACT

The slave-making ant *Polyergus lucidus* is reported for the 1st time from Florida. *Formica archboldi* is its host species, not previously known to be parasitized in this way. The behavior of these 2 species is described and compared to that of related forms from other regions.

RESUMEN

Se registra por primera vez la hormiga esclavista *Polyergus lucidus* de la Florida. *Formica archboldi* es su hospedero, que no se conocía previamente que era parasitado de esta forma. Se describe el comportamiento de las 2 especies, y se compara con el de hormigas emparentadas de otras regiones.

Dulosis is a form of social parasitism in which the workers of 1 species of ant periodically raid colonies of related species for brood. The plundered brood is reared in the nest of the parasite by workers of the host species which serve as the nurse, forager, defense, and construction force for the mixed colony. Often referred to as slave-making, this type of parasitism is unique to Formicidae, but has arisen several times independently within the family (Wilson 1971).

Talbot (1967, 1968), Harman (1968) and Marlin (1968, 1969, 1971) have reported on the natural history of *Polyergus lucidus* Mayr in Michigan and Illinois, and Kwait and Topoff (1983) have recently published on the species'

behavior on Long Island. This paper reports observations made in 1983 on 3 colonies of the so-called subspecies *P. lucidus longicornis* Smith near Gainesville, Florida and its host, *Formica archboldi* Smith. In the opinion of JCT, the Florida population simply represents the southern end of a spottily distributed and somewhat variable species; *P. lucidus*. In view of the morphological and (as shown below) behavioral indistinctness of the Florida *Polyergus*, we refer to these ants henceforth as *P. lucidus*. This should not be construed as a formal taxonomic change at this time.

This is the 1st record of *F. archboldi* as a slave in *Polyergus* nests. This *Formica* is a member of the *pallidefulva* group, to which most other host records for *P. lucidus* belong (Smith 1979).

Florida *P. lucidus* were observed in a turkey oak-long leaf pine sandhill community with sparse clumps of wire grass and patches of gopher apple as ground cover. Other ants common at the site are *Formica pallidefulva* Latreille, *Camponotus socius* Roger, *C. floridanus* (Buckley), *Paratrechina arenivaga* (Wheeler), *Leptothorax pergandei* Forel, *Solenopsis pergandei* Forel, *S. geminata* (F.), *Pogonomyrmex badius* (Latreille), *Aphaenogaster floridana* M. R. Smith, *Pheidole morrisi* Forel, and *Odontomachus brunneus* (Patton). *Prenolepis imparis* (Say) is conspicuous from November through April, but is inactive on the surface during the warmer months.

Observations

Raiding and Associated Behaviors

On 22 May CJ discovered a column of *P. lucidus* workers (from Colony I) crossing a path at 1800 h EDT running very rapidly toward their nest at the base of a wire grass clump. Each worker bore a pupa from the raided nest. Upon reaching their own nest, the workers entered it quickly and did not reappear. In subsequent observations, returning *P. lucidus* were always seen to carry stolen *F. archboldi* brood directly into the nest. This differs from JCT's oft-repeated observation of *P. breviceps* Emery in Illinois, Colorado, and New Mexico, in which the returning raiders hesitate at the nest entrance, where they drop off the plundered brood, which is then carried by the *F. fusca* L. slaves into the nest.

Colony I was visited on several occasions in June and early July but it was not until 9 July that a raid was observed. On each previous visit, observations were made from 1600 h or 1700 h until 1900 h, but we saw little or no *P. lucidus* activity. On 9 July, the *P. lucidus* made 4 consecutive raids on a large colony of *F. archboldi*. Beginning about 1730 h, 3 *Polyergus* workers emerged one by one and milled about the nest entrance for a minute or two before leaving the nest in various directions. Shortly before 1800 h, one was seen returning hurriedly. By this time, 10 workers were milling about the entrance. The returning scout entered the nest. After less than one minute a group of 25 workers set off in a compact column in the direction from which the scout had come. In a few minutes, they arrived at and immediately entered the *F. archboldi* nest. Several dozen *F. archboldi*, some bearing brood, scurried out from their nest and took cover under nearby leaves. The *P. lucidus* soon reemerged and headed speedily for home. They entered their nest without hesitation. After 60-90 seconds they reemerged, milled about the entrance for a minute or two, then set off again. On the first raid, 25 workers participated and 21 returned with pupae. (Cor-

responding numbers for the subsequent 3 raids were 31, 25; not counted, 25; and 36, not counted). Thus between 80 and 100 pupae were robbed from a single host colony by a work force of no more than 36 *P. lucidus* workers. This sort of repeated raiding was called a "compound raid" by Marlin (1969).

On 10 July, Colony I raided 2 separate *F. archboldi* colonies (i.e. the "multiple raid" of Marlin 1969). Both *F. archboldi* colonies were small, as only a small number of diminutive *F. archboldi* individuals were flushed when the *P. lucidus* entered their nests, and only about 20 of the *Polyergus* returned laden from each raid, some bearing larvae, rather than the usual pupae. The 1st of the 2 raids occurred between 1735 and 1800 h. The 2nd raid began at 1815 h and went in precisely the opposite direction from the 1st. The 1st raiding party was accompanied by a dealate *P. lucidus* queen, who was frequently at the head of the column, as reported by Marlin (1968). The queen did not return with the laden workers, but remained in the raided nest.

On 14 July, *F. archboldi* slaves from Colony I were observed carrying brood to a new nest site about 4 meters from the original nest. *F. archboldi* slaves carrying brood were followed to the new site. On 15 July, at 1730 h, 24 *P. lucidus* left in the direction of their old nest, apparently on a normal raid. Upon arriving at the old nest, the raiders entered and remained inside for 4 minutes. Over the next 10 minutes, the *P. lucidus* emerged 1 by 1 carrying *F. archboldi* workers held in the characteristic pupoid pose of ants during social carrying. Two *Polyergus* were carried by *Formica* workers in the same way. This rather spectacular mode of aiding in colony emigration was reported recently by Kwait and Topoff (1983), who considered such behavior an adaptive alternative use of the generally implastic raiding behavior of *Polyergus*. It is not surprising that *Polyergus* colonies relocate periodically, as this may help them avoid local depletion of host colonies from which to steal brood.

On 16 July, 33 workers from Colony I emerged at 1807 h and headed in the direction of their old nest. Upon arriving at the old nest, 6 workers entered it, while the others milled around the entrance. Two minutes later, the 6 had resurfaced and the procession continued in the same direction. After 6 minutes, they reached and entered a *F. archboldi* nest. In less than a minute 28 *P. lucidus* bearing pupae, and 1 bearing a larva emerged and ran quickly toward their nest. The unladen workers straggled behind.

On 15 July, CJ discovered a 2nd *P. lucidus* colony (Colony II). The workers were crossing another portion of the same path on which the 1st was found, at 1803 h. At 1820 h they arrived at a large colony of *Formica* whose nest was concealed beneath leaves. Thirty-two *Polyergus* participated in the raid: 28 returned laden. In a 2nd raid on the same host nest, 26 went out, and 25 returned of which 24 carried pupae. The missing worker fell into an antlion pit and was killed on the outward portion of the raid. On 16 July, 30 workers from Colony II left at 1740 h along the same path as the previous day, but never reached a host nest. By 1800 h all *P. lucidus* had straggled back to their nest.

In the summer of 1984, CJ discovered a 3rd *P. lucidus* colony about 100 m WNW of Colony II, in the ecotone between the sandhill community in which Colonies I and II were located and the more mesic woodland to the west. Colony III was a larger colony; counts made during 1 raid observed by CJ

and 1 observed by JCT both yielded about 45 workers. Colony I was not rediscovered in 1984, but Colony II was found nesting beneath a wiregrass clump about 2 m south of its previous nest site. The population of Colony II had increased since 1983 when it contained 25-30 workers. Several highly successful compound raids on large *F. archboldi* colonies by groups of 36-38 *P. lucidus* workers from Colony II were observed in 1984. A raid in which the *P. lucidus* never reached a nest of *F. archboldi* was observed once each in Colonies II and III. Several *P. lucidus* workers from both of these colonies were caught by antlions while conducting raids.

On several occasions, *F. pallidefulva* nests or workers were seen near *P. lucidus* nests or raiding columns. However, *F. pallidefulva* is apparently not enslaved by the *P. lucidus* population under study, as *P. lucidus* were never seen to raid colonies of the former, nor were *F. pallidelfulva* ever observed among the slave-force of *P. lucidus* colonies.

Natural History of *F. archboldi*

Schneirla (1944) presented information on the biology of *F. archboldi* at the Archbold Biological Station in Highlands Co., Florida. In the sandhills near Gainesville, Florida, *F. archboldi* nests at the base of grass clumps, or in a nest concealed by leaf litter. On 1 occasion JCT saw them build a small earthen mound about 10 cm in diameter in which they incubated their sexual pupae, but this was in a shady, more mesic site than that in which the other observations reported here were made. Based on several years of collecting in the area, we believe this species prefers scrub or sandhill and other more open vegetation in northern Florida.

F. archboldi colonies are very likely to emigrate after disturbance. All colonies raided by *Polyergus* had moved away by the next time they were observed (usually the next day). Also, unraided colonies from which some of the leaf litter or grass cover was removed, were found to have moved away within a few days. The nest entrances were always cryptic before the colonies were disturbed.

In the sandhill community, *F. archboldi* was a predominant ant observed foraging on vegetation, especially around nectaries, galls, and homopterans. They were much more abundant than the number of nests found would indicate.

Two of the 8 colonies were polygynous; one with 2 dealate females and one with 4. The colony with 4 had only about 25 small workers and almost certainly represented one recently founded pleometrotically.

The prey records of *F. archboldi* are particularly interesting. Foraging activity was especially high in the morning and between 1600 h and 1800 h (especially during the 1st hour of this period). The following records of prey being carried into *F. archboldi* nests were accumulated over several afternoons in late June and July: 8 *Odontomachus*; 1 *Pogonomyrmex*; 2 *S. geminata* females; 1 *S. geminata* male; 1 *S. pergandei* female; 1 tipulid pupa; 2 small cercopids; 2 scarab beetles; 1 subadult *Pictonemobius* cricket; 3 unripe *Stellaria* fruits; 3 *Pinus* "male cones", and 1 grasshopper fecal pellet. All of the ants and most of the other insects brought in were still limp and presumably fresh-killed, though no actual killing was observed. In the case of the cricket, 4 workers cooperated in carrying the prey toward the nest from over 1 m away. Two *F. archboldi* corpses and 1 of *P. lucidus* were carried over 2 m away from the nest and discarded, but CJ excavated

a nest of *F. archboldi* in which subterranean refuse heaps contained remains of numerous *Odontomachus* workers.

Discussion

In these observations, a good portion of the range of behaviors seen in more colonies over a much longer total period of time by earlier authors (see ref. cit.) were seen. The biology of this Florida population of *P. lucidus* is remarkably like that of the northern populations. Marlin (1971) summarized the known biology of *P. lucidus*. To his summary and the data in Smith (1979) may be added the following points, some of which apply specifically to the Florida population:

(1) The range of *P. lucidus* extends south to at least Alachua County, Florida.
(2) *P. lucidus* uses *F. archboldi* as host, within the latter's range in Georgia and Florida.
(3) Raiding occurs in late spring and early summer. No raids have been observed after mid-July, despite repeated visits at the appropriate time of day. It is not known if raids occur before mid-May.
(4) Alate queens and males were observed emerging on hot, cloudless days in June and early July. No alates were observed after the 1st week of July. Mating was not observed but the dealate queen mentioned above seems likely to have been newly mated.
(5) Colony populations were small, with from 25 to perhaps 50 workers participating in raids. It is believed that the colonies were mature because they had fully-colored, full-sized workers.
(6) Only a few, perhaps a dozen, raids are conducted each season, though some or perhaps most are multiple or compound raids, especially the latter. No raids were observed on most days when the colonies were watched.
(7) *Polyergus* workers aid in relocation of nests by performing an emigration-raid at their old nest and carrying slaves to the new nest site. This was observed independently by Kwait and Topoff (1983).
(8) On no occasion were the *Polyergus* observed to kill *Formica* or even fight with them. The latter simply fled when their nest was entered by *Polyergus*, then reentered after the *Polyergus* left.

In some of these points, particularly #3, #4, and #5, this southern population of *P. lucidus* resembles the Southern California population of *P. breviceps* Emery (R. R. Snelling, Natural History Museum, Los Angeles Co., pers. comm.). The host of the latter is *Formica occidua* Wheeler, not previously reported as a slave species. *F. occidua*, an abundant *F. fusca*-group species of southern California, is also enslaved by *F. subnuda* Emery in the same region (JCT, unpub. obs.).

Much remains to be known about these and other ants inhabiting the scrubland and sandhills of Florida, which together constitute some of the least studied ant communities in North America. Unfortunately, due to their suitability for development, such habitats are among the most rapidly disappearing in the region. These interesting areas should be studied while they last.

Acknowledgement

We especially thank Daniel P. Wojcik and Ellen C. Kwait, for their

constructive criticisms of the manuscript. This is Florida Agricultural Experiment Station Journal Series No. 5742.

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SOCIAL BEHAVIOR IN PASSALID BEETLES (COLEOPTERA: PASSALIDAE): COOPERATIVE BROOD CARE

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ABSTRACT

A brief summary is given concerning passalid social behavior in relation to their life cycle. Passalid pairs defend log tunnels and remain with offspring from egg to adulthood. Parent-offspring cooperation involving care of other offspring is a step in the evolution of eusociality. Young adult passalids cooperated with their parents in repair of sibling pupal cases. Cooperative brood care between parents and juveniles has not been reported previously for non-Hymenopterous or non-Isopterous arthropods. The presence of overlap of generations and cooperative brood care by at least temporarily non-reproductive adult individuals in certain passalid species suggest that we might consider these passalids to possess one of the highest levels of subsocial behavior known for arthropods. Habitat, trophic rela-

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A brief summary is given concerning passalid social behavior in relation to their life cycle. Passalid pairs defend log tunnels and remain with offspring from egg to adulthood. Parent-offspring cooperation involving care of other offspring is a step in the evolution of eusociality. Young adult passalids cooperated with their parents in repair of sibling pupal cases. Cooperative brood care between parents and juveniles has not been reported previously for non-Hymenopterous or non-Isopterous arthropods. The presence of overlap of generations and cooperative brood care by at least temporarily non-reproductive adult individuals in certain passalid species suggest that we might consider these passalids to possess one of the highest levels of subsocial behavior known for arthropods. Habitat, trophic rela-

tions between individuals, and sex determination mechanisms suggest parallels with the evolution of termite sociality.

RESUMEN

Se resumen brevemente lo que se conoce acerca del comportamiento social de passalidor en relación a su ciclo de vida. Parejas de pasálidos difienden túneles en palos y se quedan con su prole desde huevo hasta adulto. Cooperación entre padres y prole involucrando cuidado de otra prole, es una etapa en la evolución de la eusocialidad. Jóvenes adultos cooperaron con sus padres en la reparación de capullos pupales de sus hermanos. Cuidado de la cría en cooperación entre padres y juveniles no ha sido reportado anteriormente para los artropodos no-Hymenopteros o no-Isopteros. La presencia de traslape de generaciones y cooperación entre adultos y prole que son temporalmente no-reproductivas en algunas especies de pasálidos, sugiere que estos pasálidos poseen uno de los niveles conocidos más altos de comportamiento subsocial entre los artrópodos. Habitat, relaciones tróficas entre individuos y mecanismos de determinación de sexo, sugieren paralelas con la evolución de la eusocialidad en termitas.

Cooperative broad care, overlap of parental and offspring generations, and the presence of reproductive castes are the basic characteristics which define truly social (eusocial and hypersocial) behavior in arthropods (Batra 1966, 1977). These high levels of social behavior are recognized among the arthropods primarily in the Hymenoptera and Isoptera. Some arthropods have forms of subsocial or quasisocial behavior with 1 or rarely 2 of these characteristics developed to varying degrees (Wilson 1971, Eickwort 1981). Passalid beetles are among the most highly subsocial insects because they possess, in at least some species, both overlap of generations and, as we report here, cooperation in brood care between parent and offspring. Young adult passalids cooperate with their parents in repair of sibling pupal cases. Cooperative brood care is rare (unknown?) for arthropods other than Hymenoptera or Isoptera. Habitat, trophic relations between individuals, and sex determination mechanisms suggest parallels with the evolution of termite sociality.

The family Passalidae contains approximately 500 species of primarily tropical, wood-eating beetles that tunnel in rotting logs (Reyes-Castillo 1970, Schuster 1978). One beetle (either sex) arrives at a log and begins a tunnel. The other beetle which will form the pair arrives later. The beetles are monogamous and the pair remains together at least through the development of the first brood. They will defend the tunnel against other passalid intruders (Schuster 1975). Acoustical communication is highly developed in the colony, especially associated with courtship and aggression. One species has at least 17 signals, more than is known from any other arthropod (Schuster 1983).

Eggs are placed in a nest of finally triturated wood in the tunnel. Though Krause and Ryan (1953) mention 100 eggs and juveniles of the first larval instar in a nest of *Odontotaenius disjunctus* (Illiger) (formerly *Passalus cornutus* Fabricius and *Popilius disjunctus* Ill.), Gray (1946) noted nests of this species usually contain 20-35 eggs. In various countries we examined a total of 28 natural passalid nests by carefully dissecting the tunnel systems; the maximum number of progeny (eggs and young larvae)

in a nest was 42 for *Chondrocephalus purulensis* (Bates) in Guatemala. In some tropical species a pair can produce 3, and perhaps 4, egg clutches in a year (Schuster 1975). We observed courtship of *O. zodiacus* (Truqui) in the presence of third instar larvae; occasionally, we found pupae and eggs in a tunnel system without any intermediate larval stages. Apparently, therefore, when a brood is in or near the pupal state, another egg clutch may be produced. It is not necessary, however, for the male to be present (though apparently he usually is) for subsequent egg clutch production. A female *Publius agassizi* (Kaup) collected in May and maintained completely isolated from other passalids produced a clutch of fertile eggs at 4 months and another a year after capture. Nevertheless, it is rare to find single beetles in a tunnel system except at the initial stage of excavation.

In Passalidae, black (mature) adults are found in tunnels with all ontogenetic stages, including red (teneral) adults. In 76 passalid tunnel systems containing juveniles of 37 species in Peru, Costa Rica, Mexico and Guatemala, mature adults were present in all except 2 systems. Of 17 systems with at least 1 teneral adult, 16 also contained at least 1 mature adult. Since teneral adults require a few weeks to many months to blacken entirely, this suggests a minimal duration of parent-adult progeny contact. Usually, only completely black adults migrate (Schuster 1975). Of 51 migrating passalids captured in Guatemala, 40 were black, 11 were intermediate in color and none were red. The presence of more than 2 black adults in 1 tunnel system indicates that migration may not necessarily occur immediately upon blackening. This inference is strengthened by the aggressive behavior of colonists toward intruders, reducing the probability of foreign beetles joining the colony; thus all black beetles in a colony should be either parents or progeny. The maximal duration of generation overlap may depend on resource availability and consumption rate, or on adult longevity. Adults live more than 2 years in the field, and in the laboratory a pair of *Passalus affinis* (Percheron) survived 4 years. Individuals of *P. punctiger* Lepeletier & Serville and *O. zodiacus* continued reproducing after 2 years.

Very little is known concerning the life and behavior of the larvae until pupation. A third larval instar pupates in a case of fine-textured, compacted excrement and wood shreds constructed with adult aid (Fig. 1). This case may be important in protecting the pupa from predation or parasitism. Reduviids and tachinids are known to attack passalids (Schuster 1975). About 5 days prior to pupation, the larva ceases feeding, becomes whiter, and enters a pre-pupal stage. In the absence of adults, the prepupa will roll over and over, forming a depression in the feces and wood shreds. It will pupate in this depression. When adults are present, they will aid the larva in pupal case construction, as described by Miller (1932) from laboratory observations of *O. disjunctus*, by piling case material on the prepupa and shaping it from the outside. Two or more adults may work on the same case concurrently, or a single adult may work alone. Males and females may participate in construction.

The presence of parental brood care and generation overlap allows the possibility of cooperative brood care between parents and adult offspring, apparently quite rare outside the Hymenoptera and Isoptera. In Passalidae, parents, teneral adults, pupae and older larvae are commonly found together in the same tunnel system, a situation obviously conducive to cooperative brood care. In some cases, even greater overlap occurs, e.g. a chamber ap-

Fig. 1. *Passalus punctiger*—pupal case containing prepupa.

proximately 18 cm long in a Mexican log contained 22 *Heliscus tropicus* (Perch.) eggs, 4 first instar and 1 third instar larvae, 3 pupae, 10 teneral adults, and 3 black adults. Passalid iteroparity augments the potential for cooperation.

Evidence of sibling cooperation has been observed in pupal case construction. Miller (1932) observed 2 or more adults of the same sex constructing pupal cases together, but he did not give any indication of their genetic relationships. We collected 1 black and 2 teneral *Popilius haagi* (Kaup) adults and 3 larvae from the same tunnel system. Two of the larvae pupated and became adults within a week before the construction of the pupal case for the third larva. The new adults were not seen to aid the construction of the third case though construction was not observed continuously. Therefore, on 1 occasion 7 days, and another 9 days, after case construction, we made a hole 3 x 5 mm in the side of the new pupal case. Both times it was repaired by older beetles working together with a newly emerged beetle pushing frass with their mandibles and head to and against the pupal case. In the second case, the teneral beetle completed the reconstruction alone after the others had stopped working. A teneral adult emerged from the case 15 days later.

In a similar experiment with *Verres hageni* Kaup, we completely destroyed a case containing a prepupa. A black adult and 2 teneral adults

worked together in completely reconstructing the case. The slightly darker teneral adult reconstructed much more than did the very red adult. All were from the same log.

In a situation with *Passalus punctiger* a pupal case was damaged several times in the presence of the black adult that had constructed it and a teneral adult 3 days out of its case. Only the black adult repaired the case. However, when the black adult was removed a rough case was constructed by the teneral adult within 21 hours; the case was well constructed within 33 hours.

In these species, as well as 2 others (*Chondrocephalus purulensis* and *P. punctatostriatus* (Percheron)) with which pupal case destruction experiments were done only with black or dark intermediate adults, the mature adults often became quite active immediately on contacting the destroyed sections of a case. The teneral red adults were usually slower to begin construction.

These observations indicate that a beetle may cooperate with other siblings and/or its parents in the construction and repair of a sibling's pupal case. The only trait, therefore, that can separate passalids from eusocial insects is their lack of castes. In adult passalids, external morphological differences are minimal or non-existent, even between sexes, except for teneral redness. Exactly when adults become sexually mature is unknown. Young adult males are not sexually mature (Virkki and Reyes-Castillo 1972); they have spermatogonia but lack spermatozoa (Virkki 1965). These factors would make it difficult to distinguish if possible castes (differing only in degree of ovarian development) do occur in some insects (Plateaux-Quénu 1960, 1962).

The rate of ovarian development is unknown. Courtship occurred 3 months after male and female pupal ecdysis in *P. punctiger* and 4 months after ecdysis of both sexes in *O. disjunctus*, which may indicate maturation by this time. Reproduction by either sex can occur 10 to 11 months after pupal ecdysis in *O. disjunctus* (Schuster 1975).

What factors may have influenced the evolution of such a high level of sociality in passalids? The haplodiploidy (males haploid) sex determination mechanism of Hymenoptera is thought to predispose this group toward the evolution of sociality (Hamilton 1964). Trophic relationship regarding transmission of mutualistic intestinal protozoa and/or bacteria in some termites may be a key factor in the evolution of termite eusociality (Howse 1970). Termites pass their protozoa throughout the colony by anal trophallaxis, the ingestion of anal liquids by other colony members. Repeated anal trophallaxis is necessary because each time a worker molts it loses its intestinal symbionts.

In many respects, Passalidae resemble termites and their probable ancestors the cryptocercid roaches (Nalepa 1984) more than Hymenoptera. Termites have a conventional genic sex determination mechanism (Hamilton 1972), as do passalids, which have either XY variants or XO, depending on the species (Virkki and Reyes-Castillo 1973). Monogamy in passalids, as in termites, should result in a high degree of relatedness among individuals of a given colony. Though passalid intestines have no cellulose-degrading protozoa, they do have a well developed flora and fauna, especially various fungi and nematodes (Lewis 1926). Passalids fed only rotting wood lose weight and die much sooner than those that eat passalid feces or previously tritu-

rated wood which has been partially decomposed by microorganisms (Mason and Odum 1967). For this reason alone, it would be advantageous for the larvae to remain near the adults. This may also explain why the eggs are placed in a nest of finely chewed wood. Ohaus (1900) suggests that the larval jaws are too weak to eat wood directly, but Heymons (1929) refutes this on the basis of morphological and behavioral studies in the laboratory. Instead, the finely shredded wood exposes a greater surface area to attack by wood-digesting microorganisms. More nutrients then become available to the newly hatched larvae, either as by-products of this digestion or in the bodies of the microorganisms ingested.

Both termites and passalids live in rotting wood. Dead trunks harbor a large number of subsocial species of arthropods and are apparently the site of origin of at least 2 truly social groups: ants and termites (Hamilton 1978). Organisms in such stable, structured "bonanza" microhabitats are usually subjected to K-selection, which tends to favor longer life, large mature size, iteroparity, and small broods (Wilson 1975)—all characteristic of Passalidae. These, in turn, tend to favor the evolution of increased parental care (Wilson 1975).

The presence of overlap of generations and cooperative brood care by at least temporarily non-reproductive adult individuals in certain passalid species suggest that we might consider these passalids to possess 1 of the highest levels of subsocial behavior known for arthropods.

End Note

We thank S. W. T. Batra, M. Dix, J. E. Lloyd, P. Reyes-Castillo, T. J. Walker, R. S. Wilcox, and an anonymous reviewer for criticisms of the manuscript; P. Reyes-Castillo for aid in insect identification; R. L. Enríquez, A. Valenzuela, E. Valenzuela and O. Molina for typing the manuscript; and the Organization for Tropical Studies; U. S. Peace Corps-Peru; Universidad Nacional Agraria de la Selva, Tingo Maria, Peru; University of Florida; and the Universidad del Valle de Guatemala for their support and research opportunities provided. Jack Schuster is a Research Associate, Florida State Collection of Arthropods, Department of Plant Industry Gainesville, FL.

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SOUND PRODUCTION AND RECEPTION IN THE CARIBFLY, *ANASTREPHA SUSPENSA* (DIPTERA: TEPHRITIDAE)

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ABSTRACT

Virgin female *Anastrepha suspensa* (Loew) with aristae removed failed to respond to recorded male "calling" song to the same extent as intact females. However, removal of aristae did not change female response to another sound known to modify behavior: the "precopulatory" song sung by mounted males. Thus, aristae are possibly not the sole organs of sound/vibration reception. Virgin females without aristae are attracted to male-produced pheromones and the aristae bear no evidence of chemosensilla. These organs appear to be involved only in mechanoreception. Apparently the male songs of *A. suspensa* are produced solely by wings because their sound pressure levels increase in proportion to the amount of wing surface, and there are no obvious morphological features that might make up a wing powered stridulatory mechanism. There is a slight sexual dimorphism in wing shape (male wings were more oval). Comparisons among tephritids with various wing shapes and courtship signals suggest that the dimorphism might be due to male wing modification for sound production.

RESUMEN

Hembras vírgenes de *Anastrepha suspensa* (Loew) con las aristas removidas, no respondieron en el mismo grado que las hembras intactas al canto grabado de llamada del macho. Sin embargo, al quitarle las aristas, no cambió la respuesta de las hembras a otros sonidos conocidos como modificadores de comportamiento, que es las canción "pre-copulatoria" cantada por machos apareados. De aquí que las aristas no son posiblemente los únicos órganos de recepción de la vibración de sonidos. Hembras vírgenes sin aristas son atraidas por feromonas producidas por machos y las aristas no muestran evidencia de "chemosensilla". Estos órganos parecen estar involucrados solamente como receptores mecánicos. Aparentemente, el canto de los machos de *A. suspensa* son producidos solamente por las alas, puesto que los niveles de la presión del sonido aumenta en proporción a la cantidad de superficie del ala, y no hay ningún rasgo morfológico que pueda hacer un mecanismo de estridulación hecho por la fuerza motriz del ala. Hay un pequeño dimorfismo sexual en la forma del ala (las alas de los machos son mas ovales). Comparaciones entre tefrítidos con varias formas de alas y señales de cortejo, sugieren que el dimorfismo puede ser debido a modificaciones en el ala del macho para producir sonidos.

A few flies make sounds during courtship and territorial defense (Burk 1981). The best known are the "love songs" of *Drosophila* spp. (Bennet-Clark and Ewing 1970, see also contributions in Huettel 1985). However, there is information accumulating on the function and structure of acoustic signals in the Caribbean fruit fly, (caribfly) (*Anastrepha suspensa* [Loew])

(Diptera: Tephritidae). Caribflies produce 2 sounds in sexual context: the calling song, consisting of repeated pulse trains (bursts) broadcast from territories on host-plant leaves, and the precopulatory song emitted just prior to, and during insertion of the aedeagus (Webb et al. 1976). The calling song attracts females in field cages (Webb et al. 1983a) and increases the activity of virgin, but not of mated, females in the laboratory (Sivinski et al. 1984). Precopulatory song influences male acceptance by females and may be a means of advertising male vigor. Both loud volume and a continuous, non-pulsed structure increase the likelihood that a male will complete a coupling (Sivinski et al. 1984).

The means by which tephritid flies perceive these sexual messages have not been previously examined, though in another acalypterate family, the Drosophilidae, sound is perceived through the vibration of the aristae stimulating Johnston's organ on the 2nd antennal segment (e.g., Manning 1967, Ewing 1978). We show here that the caribfly sounds are produced by the wings and some are received *via* the aristae, but that these antennal structures may not be the sole organs of hearing.

Methods

Sound Reception

In order to determine the acoustic sensitivity of the aristae, adult flies were cold-anesthetized. Half of the anesthetized flies had at least 90% of their aristae removed with forceps, while the rest served as controls. Previous experiments had shown that virgin females respond to calling song with increased flight and walking (Sivinski et al. 1984). Differences in the response to sexual signals of virgin females with and without aristae were searched for in the following manner. Two observers, in an anechoic chamber, simultaneously measured activity in an experimental and in a control replication by counting the number of times 25 flies in a 20 cm x 20 cm x 20 cm screen wire cage crossed a line bisecting the cage.

Both cages had a speaker simultaneously emitting the same recorded calling song at a sound pressure level (SPL) (odB re 20 μpa) of 55 dB at cage-center (note that due to meter inertia calling song SPLs are estimates rather than precise measurements). Counts were made during 6 alternating 5-min periods of broadcast and silence. Ten replicates were performed.

To determine if aristae might have additional chemosensory properties, 15 virgin ♀♀ with and 15 without aristae were placed in an olfactometer, a device that traps females moving in the direction of an odor stimulus. Males, substantially muted by wing removal, served as a pheromone source. Dealation was an attempt to avoid confusion of signal modes, i.e., to provide both supposedly deaf and hearing females with a similar set of signals. Ten replicates were made.

Effect of Aristae Removal on Copulatory Behaviour

Precopulatory song intensity influences female reception of mounted males (Burk & Webb 1983, Sivinski et al. 1984). It seemed reasonable that if aristae removal deafened females, such flies might be less likely to allow penetration, or that males would have to sing more loudly, or for longer periods of time to overcome female resistance. We observed intact and

females without aristae enclosed individually with a male fly in a 7.5 cm x 7.5 cm screen wire cylinder. The number of rejections a male suffered, the time between introduction and copulation, and the duration of the precopulatory song were recorded.

Precopulatory song SPL was measured with a 12.7 mm Brüel & Kjaer Model 4145® condenser microphone held at 2.5 mm from the flies, and coupled through a cathode follower to a Brüel & Kjaer Model 2608® microphone amplifier and SPL meter. Note that the SPL of the relatively continuous precopulatory song can be measured without the problem of meter inertia that plagues attempts to quantify the periodic calling song.

The Effect of Changes in Wing Area on Sound Production

We clipped the wings of male caribflies resulting in losses of 40, 60, 85 and 95% of the wing area ($N_{100\ percent} = 119$, $N_{60\ percent} = 6$, $N_{40\ percent} = 7$, $N_{15\ percent} = 2$, $N_{5\ percent} = 3$). These percentages were determined by cutting a wing image projected by a microprojector onto a piece of paper. The resulting model was cut in the same manner as the wings and the fragments weighed. Clipped males were placed with virgin females and the SPL of their precopulatory songs measured in the previously described manner.

Sexual Dimorphism in Wings

If wings are organs of sound production, it might be expected that their structure would be specialized for singing in the more acoustical sex (males). The shape (length/width) of male and female wings were compared by determining the width of the wings measured through the cross vein that separates the 2nd dorsal and the 2nd basal cells, to the wing margins and the length of the distal portion of the wing from the junction of the previously mentioned cross vein with the M_{1+2} vein to the distal wing margin. Measurements were made by 2 methods, with a micrometer mounted in a stereomicroscope (n ♂♂ = 21, n ♀♀ = 20), and by microprojector that projected an enlarged image on a piece of paper (n ♂♂ = 26, n ♀♀ = 26) (see Sharp 1979). In order to search for allometric relationships between size and wing shape, the sizes of flies were determined in the micrometer-gathered data by measuring the length of a hind femur. The wings of another singing fruit fly *Toxotrypana curvicauda* Gerstacker and a silent species *Rhagoletis pomonella* (Walsh) were measured with a micrometer so that our sound production hypothesis could be tested by comparison (N_{TP} ♂ = 21, N_{TP} ♀ = 28; N_{RP} ♂ = 10, N_{RP} ♀ = 10, see respectively Landolt et al. 1985 and Prokopy and Bush 1973 for details of courtship).

Results

Sound Reception

Virgin female flies with aristae were more active during periods of calling-song broadcast than during alternating periods of silence (Wilcoxon paired test $P < 0.05$). There was no significant difference in the activities during sound and silence of females with their aristae removed ($P > 0.25$). The ability of flies without aristae to move about was not affected adversely by handling during the operation. Likewise, there was no difference in

the response of females with and without aristae to the pheromones of muted males (28 with and 39 without aristae were captured $P > .05$). Electronmicrographs of aristae showed none of the surface features (e.g., pits) associated with chemoreception. When this lack of sensilla is coupled to the undiminished response to distance pheromone by females without aristae, it seems that aristae in caribflies are not chemosensitive and are primarily mechanoreceptors.

Effects of Aristae Removal on Copulatory Behaviour

There was no indication that removal of aristae influenced copulatory behavior. Females without aristae were no more apt than intact females to reject mounted males (28% of 58 ♂♂ mounting intact females were rejected at least once, compared to 31% of 51 ♂♂ mounting aristaeless females). Nor did intact females accept males more rapidly ($\bar{X}$ 11.9 min from introduction *vs.* 13.3 min $P = 0.42$), have longer matings ($\bar{X}$ 41.9 min *vs.* 39.8 min $P = 0.49$), or have suitors that sang shorter songs ($\bar{X}$ 71.8 sec *vs.* 55.9 sec $P = 0.41$).

The Effect of Changes in Wing Area on Sound Production

The sound pressure level of a male precopulatory song decreased with decreasing surface area of the wing, suggesting that the wing is either the agent of sound production or the power source for a sound producing organ ($r^2 = 0.88$, $P < 0.01$), note that the last clipping leaves ca. 5% of the wing producing ca. 6% of the original SPL). There is no evidence of morphological features that might make up a stridulatory organ and it thus seems likely that caribfly songs are sung only with the wings with perhaps some additional vibrations of thoracic structures (see Esch and Wilson 1967).

Sexual Dimorphism in Wings

The ratio of wing length to width is significantly greater in female flies, i.e., the wings of males are slightly "stubbier" (micrometer obtained ratios $\bar{X}$ ♂ = 1.65, $\bar{X}$ ♀ = 1.69, Wilcoxon rank-sum test $P = 0.02$, $P = 0.01$; microprojector $\bar{X}$ ♂ = 1.68, $\bar{X}$ ♀ = 1.72, $P < 0.01$). This is not due to an allometric relationship; that is, there is not a change of wing shape with size that would generate a *de facto* sexual dimorphism since males are generally smaller. In fact, there is an opposite relationship in female flies where the longer the femur the less the length of the wing relative to width ($r = -.57$, $P = 0.009$). There is no significant relationship between size and shape in males. In the papaya fruit fly, *T. curvicauda*, which also produces wing generated courtship sounds, male wings are again stubbier ($\bar{X}$ ♂ = 1.90, $\bar{X}$ ♀ = 2.13, $P < 0.0001$). However the sexually silent apple maggot, *R. pomonella*, has no sexual dimorphism in wing shape ($\bar{X}$ ♂ = 1.60; $\bar{X}$ ♀ = 1.59, $P = 0.64$). The greater surface area of male wings of a given length could be a means of displacing more air and hence producing a louder sound.

Discussion

Removal of aristae inhibited female response to calling song but does

not obviously affect coupling, a process known to be influenced by precopulatory song. Perhaps the simplest way of resolving these conflicting results is to posit at least 2 sites of sound/vibration reception. It is plausible that the sound produced by a male in physical contact could be perceived through mechanoreceptors on the female body, legs and/or wings. If so, perhaps the removal of organs adapted for sensing air displacement (i.e., aristae) would not significantly affect reception of precopulatory signals or subsequent female behavior.

Averhoff et al. (1979) have argued that the aristae of *Drosophila* bear chemosensitive sensilla and that changes in behavior recorded in *Drosophila* after removal of antennae may not be due to deafness, but an inability to perceive pheromones. Both bioassay and micromorphological examination failed to find any evidence of chemosensitivity in caribfly aristae.

Evidence suggests that the caribfly sounds are solely or principally generated by wing movements. It is tempting to ascribe any differences in the wings of the sexes to modification for male sound production. However, sexual dimorphism in wing shape also might increase the signaling surface for visual displays, or reflect changes in wing loading evolved because of a dimorphism in flight activity. Comparing wing shape in tephritids with different signaling systems might help illuminate the functions of sexual dimorphism in wing shape. The reader will recall that male wings are more oval in the singing species *A. suspensa* and *T. curvicauda*. However, *R. pomonella*, which moves its wings in courtship but does not sing has no such sexual dimorphism. Male wings in the Mediterranean fruit fly, *Ceratitis capitata* (Wied.), another acoustic singer that produces both stridulatory and wing generated sounds are again stubbier than those of the female (Keiser et al. 1973, Webb et al. 1983b). Sharp (1979) has determined wing width and length using different measurements than ours for a number of tephritids. These can be used for cautious comparisons with our data (note that these data would show no sexual dimorphism in *A. suspensa*). *Dacus* spp. acoustic signals are due to stridulation (Monro 1953). *D. cucurbitae* (Coquillett) and *D. oleae* (Gmelin) have wing length/width ratios that are opposite *A. suspensa*, while *D. dorsalis* has no apparent sexual dimorphism. Thus the comparative evidence suggests that ovalness in male wings may have an acoustic function.

Acknowledgments

T. Burk, C. Calkins, T. Forrest and J. Sharp made many improvements of the manuscript which was professionally typed by E. Turner. T. Carlysle prepared and interpreted the electron micrographs. Mention of a commercial or proprietary product does not constitute an endorsement by the USDA.

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A SEX PHEROMONE IN MALES OF *MELITTOBIA AUSTRALICA* AND *M. FEMORATA* (HYMENOPTERA: EULOPHIDAE)

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ABSTRACT

A 4-choice arena was used to test for evidence of a volatile male-produced attractant in macropterous and brachypterous forms of 2 closely related parasitic wasps, *Melittobia australica* Girault and *M. femorata* Dahms. Virgin females of both species and forms were strongly attracted to freshly killed mashed and intact males and to living males. They were unresponsive toward males which had been dead for at least 5 days and toward empty controls. Mated females were indifferent to males, regardless of male condition. Bioassays implicated the abdomen as the source of the male sex pheromone in both species.

RESUMEN

Un escenario donde se le daba 4 oportunidades para escoger, fue usado para probar la presencia de un compuesto volatil producido por los machos, el cual atrae a hembras macropteras y brachypteras de dos especies de avispas parasíticas cercanamente relacionadas, *Melittobia australica* Girault y *M. femorata* Dahms. Hembras vírgenes de ambas especies y formas fueron fuertemente atraidas hacia machos recientemente muertos, tanto machacados como intactos, y hacia machos vivos. Ellas no respondieron hacia machos que tenían al menos 5 días de muertos o hacia el testigo. Hembras previamente apareadas no fueron atraidas hacia los machos, indiferentemente de la condición de los mismos. Ensayos biológicos con ambas especies indicaron que el lugar de origen de dicha feromona masculina está en el abdomen.

Melittobia is a genus of small parasitic wasps whose extreme sexual dimorphism and skewed sex ratios have attracted the attention of many scientists (Dahms 1984a). Hermann (1971) kept virgin *Melittobia* females in gelatin capsules separate from capsules with males. Surprisingly, these females chewed through their own capsules and went to the capsules with males; there, they chewed their way in or became trapped between top and bottom layers of the males' capsules. Based on these observations, Hermann et al. (1974) suggested the presence of a "male calling pheromone" in *Melittobia chalybii* (= *australica*). An apparent male pheromonal role in courtship of 2 *Melittobia* species was also noted by Evans and Matthews (1976). The present study was undertaken to further determine the nature of the presumed attractant.

MATERIALS AND METHODS

Wasps. The 2 species in this study, *Melittobia australica* Girault and *M. femorata* Dahms, were obtained from cultures maintained in our laboratory

at the University of Georgia. Originally collected in 1983 as parasites of the mud-dauber, *Trypoxylon politum* Say, from the vicinity of Athens, Georgia, the wasps were identified according to Dahms (1984b).

Virgin females were isolated as late pupae and used within 24 h of eclosion. Mated females were of unknown ages and were collected as they crawled from the open top of culture vials containing numerous males. Males were of unknown ages and experience and were collected directly from the cultures.

Melittobia females are polymorphic (Schmieder 1933, Freeman and Ittyeipe 1982). Because the forms differ in some aspects of their behavior (Freeman and Ittyeipe 1982), each was used separately, and forms were never intermixed. The morph used (macropterous = type form, brachypterous = second form) is indicated for each experiment.

Experimental Apparatus. Initial experiments used an airflow olfactometer described by Vet et al. (1983) for studies of other small parasitoid wasps. However, absence of air movement and the relatively small space characteristic of the natural habitat of *Melittobia* (e.g. the host cocoon), suggested that another design might provide a more realistic bioassay. Therefore, for the bioassay experiments, a small plastic container was modified to serve as an experimental arena (Fig. 1). Gelatin capsules (choices) were inserted into holes drilled at 4 equidistant points around the perimeter of the container. One half of each capsule, with an end snipped off to allow entry into the plastic container, was permanently affixed to it with paraffin wax. The other half was removable. A fine mesh screen (4 sq/mm), through which females could pass, was attached to the inside

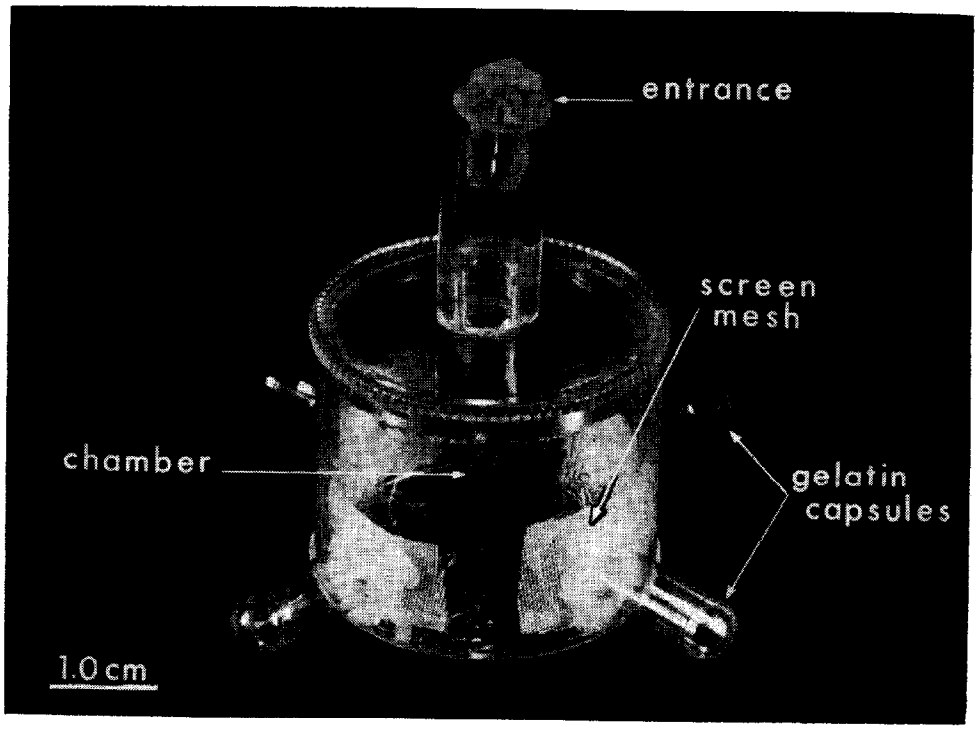

Fig. 1. Experimental apparatus used in experiments on *Melittobia* attractants.

of the chamber wall by melting the plastic and embedding the screen. A tube pushed through a hole drilled into the center of the container lid allowed introduction of experimental subjects into the container's main chamber.

General Methodology. At the start of each trial, various combinations of *Melittobia* wasps (see below) were placed in the capsules. Groups of 14-25 females were introduced into the main chamber. Once each hour for the next 4 h, the number of females present in each choice capsule was recorded. Counts were terminated after 4 h because preliminary observations indicated that by this time all females could be presumed to have had the opportunity to mate.

To control for the possibility of odor contamination, new capsule halves were used to hold the choices for each trial. To avoid possible effects of light, all trials were run in total darkness and observations were made using a flashlight with a red filter. To remove possible bias due to positional effects, the apparatus was rotated each time data were collected. In replicate trials, the choices were randomly arranged in the capsules. Experiments were run at room temperature and set at different hours between December 1983 and July 1984.

Statistical Analysis. To test the assumption that experimental replicates came from populations having identical behaviors, a heterogeneity Chi-square analysis (Zar 1974) was performed on the replicated trials of each experiment. In all cases, the null hypothesis was not rejected ($\alpha = 0.05$); therefore the data were considered to be homogeneous and subsequent statistical analyses were performed on the pooled results for each experiment. Contingency and goodness-of-fit Chi-square tests were used in the data analyses.

Experimental Protocol. The following questions were experimentally addressed:

1. Are virgin females attracted to other *Melittobia* or are they dispersing at random? Experiment 1 was run using only empty capsules as the 4 choices to determine whether females might end up in the capsules simply as a result of their efforts to disperse from the chamber and whether any features of the apparatus itself might influence wasp dispersion.
2. Are virgin females attracted more to newly eclosed males than to dead or living females or dead males? If so, is this attraction chemically cued? Experiment 2 offered virgin females choices between living males, living mated females of the same morph, and males and mated females which had been freshly killed by mashing them with the blunt end of a camel's hair brush handle.
3. Is the presumed attractant a rapidly decaying volatile chemical? In experiment 3, virgin females were offered live males, freshly mashed males, and "old" and "new" dead but intact males. "Old" dead males, taken from defunct cultures, had been dead for at least 5 days. "New" dead males were taken alive from their culture and quickly killed by close range (<2 cm) exposure to heat from a 40 watt incandescent bulb for 1 min. This treatment presumably left the body juices intact, in contrast to the mashed males whose body juices were exposed.
4. Is the attractive substance a true sex pheromone, differentially attractive to virgin females? The same choices offered in experiment 3

were repeated in experiment 4, but the test females were known to have been previously mated. Females become refractory after mating (Matthews 1975). Therefore, if the attractive substance were truly a sex pheromone rather than a generalized aggregant/arrestant, then mated females should be much less responsive to it than virgin females would be.

5. Finally, what body region is the source of the attractive substance? For experiment 5, we carefully dismembered live males and placed each body portion (head, thorax, and abdomen) into different choice capsules, with the 4th capsule left empty as a control.

RESULTS

From observations under red light, it was apparent that wasp distribution in the chamber and choice capsules had reached an equilibrium by the end of the first hour. Either females that had made their choices remained mostly stationary, or movements in and out of the choice capsules canceled out each other. Although data were recorded over a 4 h period, there were no discernable changes in distributions and census data in hours 2, 3, and 4, and the data were considered equivalent. Because over time the females' behavior appeared increasingly to switch to a dispersal mode, thereby possibly confounding the results, subsequent analysis generally used only counts made at the end of the first hour. However, analyses using means of the 4 hourly counts produced the same levels of statistical significance as did those based on the first hour counts, so in some cases data are presented as means of the 4 hourly censuses.

Experiment 1. Virgin *Melittobia* females were not attracted to empty choice capsules. Only once was a female recorded in a choice capsule at the hourly census. This distribution was in strong contrast to the experimental results discussed below, where in every case except experiments 4 and 5, more than half of the introduced females were recorded from 1 or more of the 4 choice capsules. Therefore we conclude that females arrive in the capsules as a result of active choice, not random dispersal.

Experiment 2. From Table 1, it is apparent that virgin females offered a

TABLE 1. VIRGIN FEMALE *Melittobia* ATTRACTION TO CONSPECIFIC MALES AND FEMALES, DEAD AND ALIVE.

Female Species and Form	Wasp in Capsule: Male Dead	Male Alive	Female Dead	Female Alive	Sample Size[2]
australica					
brachypterous	25.75 ± 0.96[1]	22.00 ± 2.16	0.50 ± 0.58	0.25 ± 0.50	70
macropterous	25.25 ± 5.25	6.50 ± 1.29	1.50 ± 1.00	2.50 ± 0.58	80
femorata					
brachypterous	21.25 ± 0.96	8.50 ± 1.73	0.75 ± 0.96	0.75 ± 0.50	68
macropterous	20.50 ± 5.97	4.75 ± 1.26	2.00 ± 0.82	1.25 ± 1.26	50

[1]Mean (±SD) of 4 counts taken 1, 2, 3, and 4 h after trial initiation.
[2]Includes females remaining in central chamber. All female wasp distributions were significantly different ($P<.001$) from random.

choice between conspecific males and females, both alive and dead, clearly preferred those capsules containing males ($P<.001$). Both morphs behaved in the same manner in this regard (*australica* $P<.25$; *femorata* $P<.75$). Similarly, there was no difference between the 2 species. Finally, although virgin females taken as a whole appeared to prefer dead to living males, the difference was not statistically significant.

Experiment 3. The attraction of virgin females to males in various conditions is shown in Fig. 2 and 3. "Old" dead intact males were not attractive to virgin females of either species. However, somewhat surprisingly, living males were the most preferred choice only for brachypterous *australica* females. Significantly more brachypterous females than macropterous females of *M. australica* preferred living males ($P<.001$), the only experiment for which the 2 morphs of a species did not behave in a consistent fashion. Both *femorata* morphs, like the macropterous *australica* form, showed the strongest preference for dead males (either intact "new" or mashed).

Experiment 4. Mated females of both species were almost indifferent to males offered in choice capsules, regardless of male condition. The majority of the released females remained in the chamber, either wandering or resting motionless, especially at the top.

Experiment 5. Responses of virgin females of both species to various body regions of a freshly trisected male revealed a decided preference for the abdominal section (Table 2). The thorax was approximately one-third as attractive as the abdomen; the head was totally non-attractive. The difference in attractiveness between the thorax and abdomen was statistically significant ($P<.001$). Neither the morphs nor the species showed any statistically significant differences in body region choice.

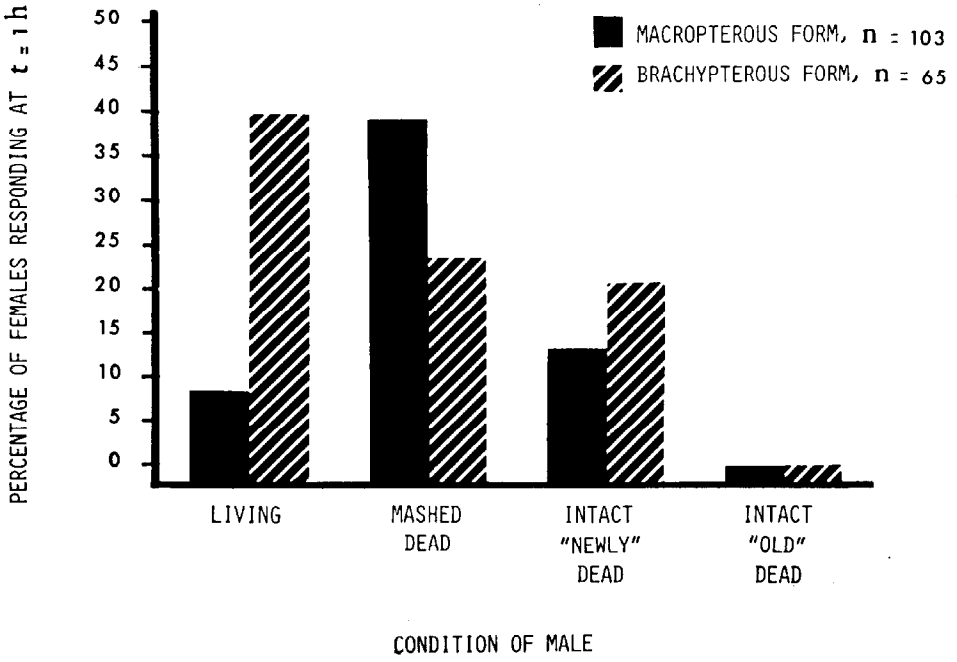

Fig. 2. Attraction of virgin *M. australica* females to conspecific males in various conditions.

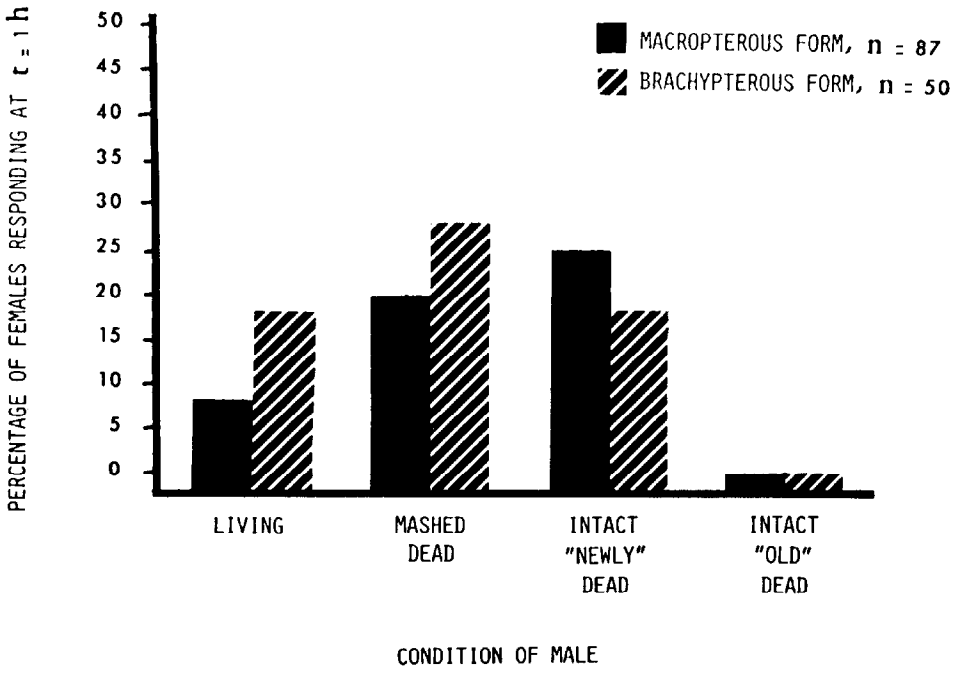

Fig. 3. Attraction of virgin *M. femorata* females to conspecific males in various conditions.

Discussion

Both the nearly complete absence of female attraction to "old" intact dead males and females' decided preferences for males in the other 3 conditions (experiment 3) provide substantial evidence that volatile chemical cues mediate this response. The strength of the response to the mashed male (particularly for macropterous *australica* females) suggests that the process of mashing allows the attractant odor to be released in greater quantity.

The pheromone probably originates from the abdominal region. In experiment 5, abdomens were 3x as attractive as thoraces, and heads were

TABLE 2. Virgin female *Melittobia* attraction to body regions of conspecific males.

Female Species and Form	Male Body Part[1]		Sample Size
	Thorax	Abdomen	
australica			
brachypterous	4.00 ± 1.83[2]	11.25 ± 1.50	40
macropterous	4.75 ± 0.50	20.00 ± 1.63	100
femorata			
brachypterous	9.00 ± 1.41	24.75 ± 4.03	108
macropterous	7.00 ± 1.41	21.00 ± 3.37	105

[1]Four choices were given (male head, thorax, and abdomen, and an empty capsule—"control"—. No females responded to capsules containing either male heads, or the control.

[2]Mean (± SD) of 4 counts taken 1, 2, 3, and 4 h after trial initiation.

totally non-attractive. We suspect that the presumed gland may be situated near the base of the abdomen; our relatively crude dissection techniques could have resulted in some contamination of the thorax portions. Histological studies are needed to resolve the question. However, courting males typically adopt a raised-wing "calling" posture (van den Assem et al. 1982), which may behaviorally corroborate the gland position.

Results of experiment 4 seem to justify calling the attractive substance a true sex pheromone, since mated females were quite unresponsive to males, regardless of condition. These results contrast strikingly to those of experiment 2, in which virgin females were used.

Because mating occurs before dispersal, and generally does not differ for brachypterous and macropterous forms of a *Melittobia* species, we would have predicted that the behavioral response of the two morphs of each species to the choices offered would be consistent. Only the brachypterous morph of *M. australica* in experiment 3 differed from the others. Although *M. australica*'s different responses may reflect differing underlying behavioral propensities, in the absence of hard data we prefer to label them "anomalous".

Male-produced olfactory cues are rare throughout the parasitic Hymenoptera (Gordh and DeBach 1978). Among the *Melittobia*, however, blind, flightless males appear to use a volatile pheromone to attract newly eclosed virgin females. Such a system appears to be highly adaptive. *Melittobia* live in the closed confines of the host cocoon, from which the females disperse immediately after mating and within which the poorly mobile males must compete with their brothers for copulations. Sex ratios are characteristically strongly female-biased (ca. 95:5), and the relatively uncommon males are often aggressive and cannibalistic toward other males (Dahms 1984a, Matthews 1975). The manner in which the blind males recognizes others of their own sex has not been investigated, but the recognition is probably chemically cued and could involve the sex pheromone.

Females of both *Melittobia* utilize the same host and displayed a similar response to male odor in our experiments. However, they belong to quite different species groups in the genus (Dahms 1984b), and their courtship patterns differ in several respects (Gonzalez and Matthews, unpublished observations). Since sexual communication systems should be expected to maintain the integrity of each species' own communication channel, the question of the existence or extent of cross-attractancy is an interesting one which will be considered elsewhere (Matthews et al. 1985).

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EFFECT OF GAMMA-RADIATED MALES ON EGG PRODUCTION IN *ACARUS SIRO*

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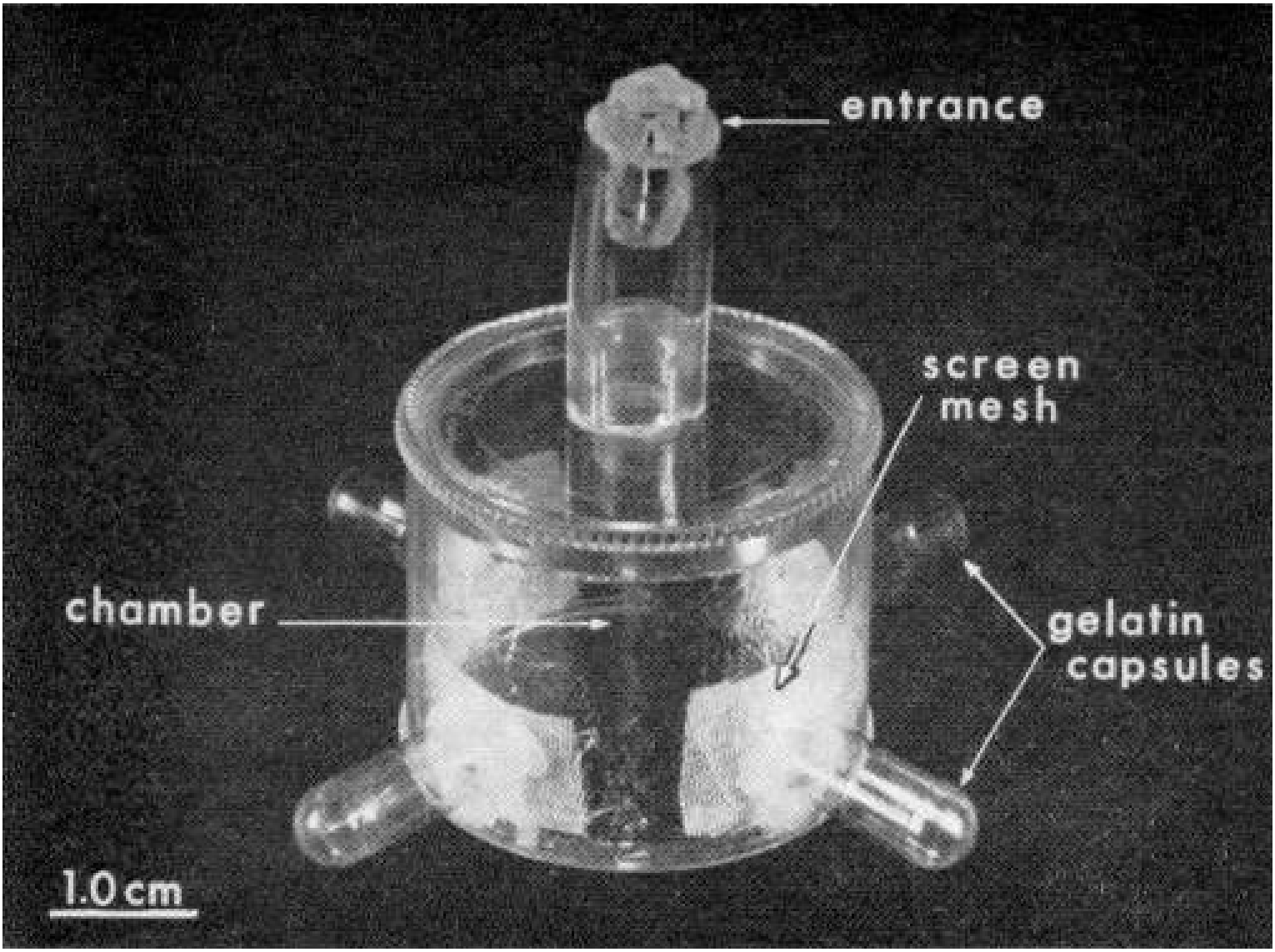
ABSTRACT

Mating of unirradiated *Acarus siro* L. females with normal and gamma irradiated males was studied. Females usually laid eggs throughout their life span if they were mated at least once a week with normal males. Females paired with treated males contained spermatophores but did not lay any eggs. Previously mated fertile females of *A. siro* subsequently mated with irradiated, sterilized males ceased egg-laying during the next 1-2 weeks. There was no significant difference when compared to the untreated control in the number of eggs laid when females were mated for one week with irradiated males and then with normal males. Weekly alternation of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mating with irradiated and normal males reduced significantly the number of eggs laid by the females and significantly reduced their longevity. Because this mite species mates many times during its life span, it is doubtful that it could be eradicated solely by the introduction of sterile males into a natural population. However, the presence of such males would decrease the number of eggs laid by normal females and it would lead to the decrease in the number of offspring in the next generation.

RESUMEN

Se estudió el apareamiento de hembras de *Acarus siro* L. no-irradiadas con normales y de machos irradiados con rayos gamma. Las hembras usualmente depositan los huevos a través de su ciclo vida si se aparean con fachos normales por lo menos una vez por semana. Hembras apareadas con machos expuestos contenían espermatoforas, pero no pusieron huevos. Previamente apareadas hembras fertiles de *A. siro* y apareadas subsequentemente con machos irradiados y esterilizados, cesaron de poner huevos durante las siguientes 1-2 semanas. No hubo diferencia en el número de huevos puestos entre el testigo y las hembras apareadas por una semana con machos irradiados y después con machos normales. Alternando semanalmente apareamientos con machos irradiados y normales, redujo significativamente el número de huevos puestos por hembras y su logevidad. Debido a que esta especie de ácaro se aparea muchas veces durante su vida, es dudoso que pueda ser erradicado en una población natural solamente con la introducción de machos esteriles. Sin embargo la presencia de tales machos disminuiría el número de huevos puestos por hembras normales, lo cual traería una disminución en el número de la prole de la generación siguiente.

The grain mite, *Acarus siro* L., is an important cosmopolitan pest of grain and grain products. Studies on the radiosensitivity of the various stages of this species and the effects of ionizing radiation on its reproductive potential determined that ionizing radiation can kill, reduce fertility and/or sterilize this species (Burkholder et al. 1966, Brown and Davis 1969 and 1972, Davis 1972, and Hemenway and Davis 1972). This was considered to be a result of polyandry that allowed residual fertile males to neutralize any effect of the sterile males. The aim of this work was to check the effect of sterile males on the reproduction of the population.

This paper reports the results of a study to determine if sterilization of a portion of the grain-mite male population offers any potential as a control mechanism.

MATERIALS AND METHODS

All grain mites used in this study were from stock colonies at the Agricultural University of Warsaw, Poland. These colonies are maintained on wheat germ at 25 ± 1°C and 89% RH. All tests were conducted under these same environmental conditions. Inert deutonymphs were selected from stock colonies and placed into individual glass cages with wheat germ as food. The next day, the adults that emerged were sexed and irradiated with 60 krad in a 60 Co irradiator at 128 rad/sec. The selection of 60 krad was made because Brown and Davis (1969) found 50 krad to be an effective sterilizing dose for males for population control. Virgin adults were then paired in the following combinations:

A—untreated (U) female with U male (control);
B—U female with U male together for 7 days, then male discarded;
C—U female with U male together for 7 days, male then replaced with U male;
D—U female with treated (T) male;
E—U female with T male for 7 days, male then discarded;
F—U female with U male for 7 days, male then discarded and replaced with T male;
G—U female with T made for 7 days, then male discarded and replaced with U male;
H—U female paired alternately with a T and a U male every other week;
I—U female paired alternately with a U and a T male every other week.

In pairing combinations H and I, all mites in each set of pairings were the same age. Fecundity was determined by counting and discarding eggs each week. At least twenty-two pairings were used in each combination.

Results and Discussion

Female grain mites in mating conditions B lived the longest (Table 1), but not significantly longer than those in conditions A, D, E, F, and G. Mites subjected to mating conditions H and I had a significantly shorter mean lifetime than those in all other test conditions. This situation may be a result of repeated copulation with the males (harassment) as noted by Boczek (1957). The means of egg production for conditions A, B, and C were not significantly different. Males sterilized by irradiation transfer spermatophores when mating (unpublished results), but the females never were observed to lay eggs (Table 1D and E). In earlier tests, mites treated with the same dose laid singular eggs.

Females which were mated with untreated males at least once a week (A and C) usually laid eggs continuously throughout their lives (Table 2). Boczek (1957) found that female grain mites had their maximum egg production with one mating per week; with mating conditions B and F, sig-

TABLE 1. Longevity and oviposition of female *Acarus siro* as affected by nine mating conditions. Results are means resulting from 22-35 male/female pairings.[1]

Mating Condition	Longevity (weeks)	Oviposition (# of eggs)
A	4.8 [a,b]	119.3 [a]
B	5.6 [a]	97.7 [a,b]
C	4.4 [b,c]	122.0 [a]
D	5.1 [a,b]	— [2]
E	5.2 [a,b]	— [2]
F	5.2 [a,b]	64.9 [c,d]
G	4.8 [a,b]	82.6 [b,c]
H	3.7 [c]	40.5 [d]
I	3.7 [c]	73.9 [b,c]

[1]Means followed with the same superscript are not significantly different at the 5% level.
[2]No eggs were laid; not included in analysis.

TABLE 2. MEAN NUMBER OF EGGS LAID PER WEEK BY *Acarus siro* AS A RESULT OF NINE DIFFERENT MATING CONDITIONS.

Week	Condition A	B	C	F	G	H	I
1	45.2 [a]	56.1 [a]	49.5 [a]	46.3 [a]	0.0 [c]	0.0 [c]	45.6 [a]
2	33.0 [a,b]	40.5 [b]	30.0 [a,b]	16.4 [b]	46.6 [a]	25.8 [a]	9.2 [b]
3	26.4 [a,b,c]	1.5 [c]	23.3 [a,b]	1.7 [b]	21.2 [b]	4.6 [b,c]	15.8 [b]
4	10.0 [b,c]	0.4 [c]	25.3 [a,b]	0.5 [b]	22.1 [b]	18.6 [a]	3.8 [b]
5	5.9 [c]	0.0 [c]	7.4 [b]	0.3 [b]	4.5 [c]	2.4 [c]	13.6 [b]
6	2.5 [c]	0.0 [c]	3.3 [b]	0.0 [b]	10.7 [b,c]	16.8 [a]	2.7 [b]
7	2.0 [c]	0.0 [c]	5.5 [b]	0.0 [b]	2.5 [c]	0.0 [c]	0.0 [c]
8	0.0 [c]	0.0 [c]	2.0 [b]	0.0 [b]	1.5 [c]		
9		0.0 [c]		0.0 [b]	0.0 [c]		

[1]Means followed with the same superscript letter within a column are not significantly different at the 5% level.

nificant reductions in egg production occurred after removal of the untreated male. In 1977, Griffiths and Boczek observed in this mite that several matings can occur within one week resulting in the placement of several spermatophores in the female spermatheca. It appears from conditions B, H, and I that such a surplus of spermatophores will only provide viable sperm for slightly more than one week at a near maximum rate of egg laying.

The overall fecundity of the females in test condition G was little affected by an initial pairing with a treated male when total number of eggs is compared with test condition A (control). The introduction alternatively of treated and untreated males on a weekly schedule (test conditions H and I) caused increases and decreases in egg laying that, in most instances, were significant and were related to the kind of male used (Table 2).

The use of introduced sterile males to control a population of the grain mite would be questionable. The level of control would be dependent upon the ratio of sterile to normal males achieved within the population and the duration this ratio was maintained. Brown and Davis (1969) found that sublethal doses of gamma radiation could be used to cause a distinct reduction in grain mite populations, but eradication was questioned.

ACKNOWLEDGEMENT

This study was supported by grants from the USDA and the Marie Sklodowska-Curie Fund (PL-ARS-98 and 104).

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FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE): FIELD SURVIVAL OF F_1 LARVAE FROM PARTIALLY STERILE PARENTS

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ABSTRACT

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith), larvae from both irradiated (10 krad) and normal parents were compared for their ability to survive under field conditions on whorl-stage sweet corn and under laboratory conditions on a meridic diet. Survival rates for F_1 larvae from irradiated and normal parents were similar under laboratory and field conditions. Implications of the use of inherited sterility for the control of fall armyworm are discussed.

RESUMEN

Larvas del cogollero, *Spodoptera frugiperda* (J. E. Smith), de padres irradiados (10 krad), fueron comparadas por la habilidad de sobrevivir bajo condiciones de campo en la etapa verticular del maiz dulce y bajo condiciones de laboratorio en una dieta merídica. Grados de sobreviviencia de larvas F_1 de padres irradiados y de padres normales fueron similares bajo condiciones de laboratorio y de campo. Se discuten las implicaciones del uso de esterilidad hereditaria para el control del cogollero.

The potential of inherited sterility as a component of area-wide management of the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), was suggested by Knipling (1980) and later demonstrated in laboratory studies by Carpenter et al. (1983). These researchers used a theoretical model to aid in understanding the potential effect of persistent genetic suppressive action through several successive generations and concluded that males irradiated with a substerilizing dose (10 krad) would be 6.7 times more effective in suppressing FAW reproduction than completely sterile males. One assumption of the theoretical model was that the magnitude of deleterious effects during the growth and development of the F_1 generation

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FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE): FIELD SURVIVAL OF F_1 LARVAE FROM PARTIALLY STERILE PARENTS

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ABSTRACT

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith), larvae from both irradiated (10 krad) and normal parents were compared for their ability to survive under field conditions on whorl-stage sweet corn and under laboratory conditions on a meridic diet. Survival rates for F_1 larvae from irradiated and normal parents were similar under laboratory and field conditions. Implications of the use of inherited sterility for the control of fall armyworm are discussed.

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Larvas del cogollero, *Spodoptera frugiperda* (J. E. Smith), de padres irradiados (10 krad), fueron comparadas por la habilidad de sobrevivir bajo condiciones de campo en la etapa verticular del maiz dulce y bajo condiciones de laboratorio en una dieta merídica. Grados de sobreviviencia de larvas F_1 de padres irradiados y de padres normales fueron similares bajo condiciones de laboratorio y de campo. Se discuten las implicaciones del uso de esterilidad hereditaria para el control del cogollero.

The potential of inherited sterility as a component of area-wide management of the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), was suggested by Knipling (1980) and later demonstrated in laboratory studies by Carpenter et al. (1983). These researchers used a theoretical model to aid in understanding the potential effect of persistent genetic suppressive action through several successive generations and concluded that males irradiated with a substerilizing dose (10 krad) would be 6.7 times more effective in suppressing FAW reproduction than completely sterile males. One assumption of the theoretical model was that the magnitude of deleterious effects during the growth and development of the F_1 generation

would be the same under field conditions as observed in the laboratory. We designed a study to test this assumption by comparing laboratory and field survival of larvae from normal and irradiated parents.

Materials and Methods

The FAW used in this study were from a five-generation-old colony that was started from a field collection of late-instar larvae. All FAW were reared in 30 ml plastic cups (each cup infested with three 1st-instar larvae) containing meridic diet (Burton 1967). The photoperiod regime was 14 h light and 10 h dark with temperatures of 29 ± 1 and 24 ± 1°C, respectively. Relative humidity was maintained at ca. 70%. All irradiation was done with a well-type ^{60}CO source delivering 1.0 krad/min.

Male and female adults (1 to 12 h old) were treated (T) with 10 krad of gamma radiation. These irradiated adults were paired together (T♀xT♂) and with normal (N) adults (T♀xN♂, N♀xT♂). A N♀xN♂ cross was the control. In each of these four crosses, five pairs of moths were placed in each of ten 3.8 liter containers for mating and oviposition. Randomly selected egg masses were removed from the containers for laboratory and field experiments. Laboratory mortality studies were conducted according to the methods described by Carpenter et al. (1983).

Field studies were conducted on the Southern Grain Insects Research Laboratory experimental farm near Tifton, Ga. In 1982, the study area was planted with 'Silver Queen' sweet corn in rows 0.32 m apart. Each plot was 18 rows wide and 15.3 m long. Centered within this plot was a 12-row x 9.2 m area designated as the buffer zone. Outside the buffer zone to the boundary of the plot was designated as the control subplot. Centered within the buffer zone was a 6-row x 6.1 m area designated as the treated subplot. Thus, each treated subplot was surrounded by a buffer zone, and each buffer zone was surrounded by a control subplot. This design was intended to detect any movement of larvae from the treated subplots into the buffer zones. If larvae dispersed in this manner, the buffer zones would sustain more damage from larval feeding than the surrounding control subplots. The plots were placed in a randomized complete block design and replicated 9 times.

On 4 May 1982, sufficient quantities of egg masses were placed at random in the late whorl of plants within each treated subplot to yield 1000 first-instar larvae per cross per subplot. Laboratory data were used to determine differential egg hatch among the crosses. The control and treated subplots and the buffer zone of each plot were observed (50 plants/subplot) for recent larval feeding before the plants were hand-infested on 4 May and afterwards on 13 and 19 May. Since many larvae moved from the whorl to the ears during development, all corn ears and stalks within the plots were dissected on 21 May and the mature larvae found were recorded.

Experimental plots in 1983 were planted with Silver Queen sweet corn in rows 0.48 m apart. Each plot was 18 rows wide and 12.2 m long. Centered within this plot was a 6-row x 6.1 m area designated as the treated subplot. The area outside the treated subplot to the plot boundary served as the control subplot. Plots were arranged in a randomized complete block design and replicated seven times. Within each subplot, 30 plants were selected at random and flagged. Each flagged plant was hand-infested with ca. 70 eggs from the appropriate cross. Plants were infested at late whorl stage on 20

May. The flagged plants in control and treated subplots were inspected on 19 and 30 May and on 2 and 8 June for recent larval feeding. On 8 June, all flagged plants were dissected and mature FAW larvae were counted, placed in 30 ml plastic cups containing meridic diet, and allowed to pupate. The number of parasitized larvae and viable FAW adults produced from the collected larvae was also recorded.

Results

The pretreatment surveys during 1982 and 1983 indicated that the experimental plots were free from a natural FAW infestation. However, many of the corn plants were damaged due to larval feeding caused predominantly by *Heliothis zea* (Boddie) and *Ostrinia nubilalis* (Hübner).

The data (Table 1) indicate that FAW larvae did not disperse into the buffer zones since there were no significant differences between the number of plants damaged in the buffer zones and control subplots. Larval dispersal did occur within the treated subplots but was usually limited to a maximum of ca. 1.5 m along the row. On 13 May, 1982, significantly more plants were damaged in the treated subplots of NxN and NxT than in the other subplots. This trend continued on 19 May, also, to include the treated subplots of TxN. These data indicated that a buffer zone was not needed; therefore, the experimental plots were modified in 1983.

Field survival of larvae from the different parental crosses is presented in Table 2. By 13 May, a trend was established with significantly more plants damaged by larvae of the NxN cross than the TxT cross. The same relationship among the crosses was evidenced by the data collected on 19 May, by which time larvae from crosses involving normal females damaged significantly more plants than larvae from crosses with treated females. The number of mature larvae collected from the treated subplots also demonstrated this relationship since crosses involving normal females produced significantly more mature larvae than crosses with treated females.

The trend for larval damage among the crosses in 1983 was similar to that in 1982 with NxN larvae in most instances damaging the most plants (Table 3). However, in 1983 NxT was not different from the TxN or NxN but was significantly different from TxT. Considering the 1982 data, the number of mature larvae collected from treated subplots in 1983 differs from

TABLE 1. Feeding and dispersal of FAW larvae from normal and irradiated parents.[1]

	$\bar{x}$ number of plants with visible damage due to larval feeding[2,3,4]							
	13 May 1982				19 May 1982			
Plot area	NxN	NxT	TxN	TxT	NxN	NxT	TxN	TxT
Treated	12.8 a	14.8 a	10.6 a	8.8 a	25.5 a	22.8 a	15.0 a	13.9 a
Buffer	8.8 b	7.6 b	8.5 a	7.9 a	12.2 b	11.3 b	11.8 b	10.7 b
Control	7.6 b	8.2 b	8.5 a	9.0 a	10.3 b	12.4 b	11.8 b	11.9 ab

[1]Whorl-stage corn infested with egg masses 4 May 1982.
[2]n = 50.
[3]N = normal, T = treated (10 krad), female listed first.
[4]Means followed by the same letter in each column are not significantly different at 5% level, by Duncan's multiple range test.

TABLE 2. COMPARISON OF FIELD SURVIVAL BETWEEN FAW LARVAE FROM NORMAL AND IRRADIATED PARENTS, TIFTON, GA, 1982.[1]

P_1 crosses (♀ x ♂)[2]	x̄ % plants damaged due to treatments		x̄ no. mature larvae collected from treated subplots
	13 May 1982	19 May 1982	
NxN	11.8 a	30.4 a	5.0 a
NxT	8.8 ab	20.8 a	4.3 a
TxN	5.4 ab	6.8 b	1.3 b
TxT	2.4 b	5.2 b	1.6 b

[1]Means followed by the same letter in each column are not significantly different at 5% level, by Duncan's multiple range test.
[2]N = normal, T = treated (10 krad).

the number expected. All of the crosses involving treated insects produced more larvae than anticipated; however, only a few of these larvae completed their development to the adult stage. Much of the observed mortality from the mature larval stage to the adult stage was the result of parasitization by *Ophion* sp. (Table 3).

The comparison of field and laboratory survival of FAW larvae is presented in Table 4. In 1982, comparisons were given only for the larval stages. The greatest deviation between larval survival in the laboratory and in the field occurred with the TxN cross. The laboratory and field survival of larvae from other crosses was similar. In 1983, comparisons are given for the entire development of the F_1 (egg-adult). Again, laboratory and field survival of larvae from cross involving treated insects was similar.

An estimated rate of increase from P_1 to F_1 generation for FAW reared in the field was calculated from our data (Table 5). In making these calculations, FAW females were assumed to produce an average of 1000 eggs during their lifetime (Pencoe and Martin 1982, Lynch 1984). In 1982, the NxN cross suffered a 99.5% mortality rate but still produced a 2.5-fold increase during that generation. It must be emphasized that only data from the P_1 adult to the F_1 mature larvae were used for these calculations. Data from the P_1 adult to the F_1 adult were used in the calculations for 1983. In 1983, the estimated rate of population increase resulting from each cross was less than onefold, indicating that all of the crosses would experience a decline in their population levels under the tested rearing conditions. The estimated rate of population increase from TxT (0.07 x) was especially low, suggesting that under these field conditions little reproduction is possible when both parents have been irradiated with 10 krad.

DISCUSSION

Laboratory studies conducted by Carpenter et al. (1983) suggested that FAW populations may be controlled by releasing moths irradiated with substerilizing doses of gamma radiation. Large-scale field releases of the irradiated moths are needed to evaluate fully this control method. An understanding of the survival and competitiveness of the irradiated moths and their progeny under field conditions is a prerequisite to a large-scale release program. It is especially important to have this information through the

TABLE 3. COMPARISON OF FIELD SURVIVAL IN 1983 BETWEEN FAW LARVAE FROM NORMAL AND IRRADIATED PARENTS.[1]

P_1 crosses (♀ x ♂)[2]	x̄ % plants damaged due to treatment			x̄ no. mature larvae collected from hand-infested subplots	% larvae parasitized[3]	x̄ no. of adults produced from collected larvae
	30 May	2 June	8 June			
NxN	58.6 a	69.1 a	56.2 a	4.4 ab	29.0 a	3.0 a
NxT	53.4 a	53.8 a	47.6 a	6.1 a	32.3 a	1.9 ab
TxN	59.1 a	62.4 a	47.1 a	3.3 b	47.7 a	1.0 bc
TxT	23.9 b	24.3 b	23.4 b	2.1 b	36.9 a	0.3 c

[1]Means followed by the same letter in each column are not significantly different at 5% level, by Duncan's multiple range test.
[2]N = normal, T = treated (10 krad).
[3]All parasites were *Ophion* sp. Only the mature larvae collected from treated subplots were examined for parasites.

TABLE 4. COMPARISON OF FIELD AND LABORATORY SURVIVAL OF FAW LARVAE FROM NORMAL AND IRRADIATED PARENTS.[1]

P_1 crosses (♀ x ♂)[2]	% survival in 1982 (larval stages)		% survival in 1983 (egg-adult)	
	Laboratory	Field	Laboratory	Field
NxN	100 a	100 a	100 a	100 a
NxT	77 ab	86 a	62 b	62 ab
TxN	59 bc	26 b	37 bc	33 bc
TxT	43 c	32 b	24 c	10 c

[1]Means followed by the same letter in each column are not significantly different at 5% level, by Duncan's multiple range test.
[2]NxN cross elevated to 100%. N = normal, T = treated (10 krad).

TABLE 5. ESTIMATED RATE OF INCREASE FROM P_1 TO F_1 GENERATION FOR FAW LARVAE REARED UNDER FIELD CONDITIONS.[1]

P_1 crosses (♀ x ♂)[2]	1982	1983
	P_1 adult to F_1 late instar larvae	P_1 adult to F_1 adult
NxN	2.50	0.63
NxT	1.87	0.43
TxN	0.36	0.23
TxT	0.36	0.07

[1]It is assumed that one female produces 1000 eggs and that sex ratios are 1:1.
[2]N = normal, T = treated (10 krad).

first generation (F_1) after a release since most of the radiation-induced deleterious effects are manifested at this time.

The present study was designed to provide environmental stresses common to field development of larvae so that any interaction between the different crosses and rearing conditions could be detected. For example, egg masses were placed on late whorl-stage corn which provided some protection for the larvae through the third instar. At this time, however, the tassel emerged and larvae were forced to move to the ear or another whorl-stage plant to maintain a food source and protection. Other stress factors included lower rearing temperatures (12.2 to 21.1°C) than occurred under laboratory conditions, rainfall, and exposure to predators, parasitoids, and pathogens. The effects of these stress factors were great, reducing survival of the control insects to 0.13-0.5% compared to ca. 50% under laboratory conditions.

The data from this study did not detect interaction between the type of parental cross and the rearing condition of the F_1 larvae. Although actual survival rates were much lower in the field than in the laboratory, the relative survival rates among crosses changed very little. These data supported the model presented by Carpenter et al. (1983), and allowed us to remain optimistic in considering the potential of inherited sterility for controlling populations of the FAW.

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FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE) ORIENTATION AND PREFERENCE FOR SELECTED GRASSES

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ABSTRACT

Fall armyworm, *Sodoptera frugiperda* (J. E. Smith), orientation and preference for 'Coastal', Tifton 10, and Tifton 292 bermudagrass (*Cynodon dactylon* (L.) Pers.), C-181, and common centipedegrass [*Eremochola ophiuroides* (Munro) Hack.], and zoysiagrass (*Zoysia* sp.) were studied. A Y-tube was used to measure chemoreception as a mechanism for orienting fall armyworm larvae to excised grass tissue. Larvae showed a significant orientation to the chemical stimuli from all the grasses but showed no preference in paired comparisons. Multiple choice preference tests indicated that the order of preference for the six grasses was: Tifton 10 (highly preferred) > Coastal bermudagrass > common centipedegrass > C-181 > Tifton 292 > (non-preferred) zoysiagrass. Damage ratings confirmed the preference of fall armyworm larvae for Tifton 10 as it sustained 50 times more damage than zoysiagrass. No differences were observed in the host plant preference between 1st and 3rd-instar larvae.

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RESUMEN

Se estudió la orientacion y preferencia del cogollero, *Spodoptera Frugiperda* (J. E. Smith) hacia 'Coastal', Tifton 10, y Tifton 292 hierba-bermuda [*Cynodon dactylon* (L.) Pers.], C-181, hierba-centipede común [*Eremochola ophiuroides* (Munro) Hack], y hierba-zoysia (*Zoysia* sp.). Se usó un tubo en forma de Y para medir la recepción química como un mecanismo de orientación de larvas del cogollero hacia tejidos cortados de hierba. Las larvas indicaron significantemente una orientación hacia el estímulo químico de todas las hierbas, pero no indicaron preferencia en comparaciones apareadas. Pruebas de preferencia múltiples indicaron que el orden de preferencia hacia las seis hierbas fue: Tifton 10 (áltamente preferido) > hierba-bermuda Coastal > hierbacentipede común > C-181 > Tifton 292 > (no-preferida) hierba-zoysia. Evaluación del grado de daño confirmó la preferencia de larvas del cogollero por Tifton 10, que sostuvo 50 veces más daño que la hierba-zoysia. No se observó preferencia entre plantas hospederas del ler. 3er. estadio.

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), one of the most destructive pests in the southeastern and central U. S. (Luginbill 1928), is characterized by high mobility and polyphagy which make it difficult to manage. It damages not only important food and fiber crops but often severely damages grasses grown for pasture, silage, turf, or soil conservation (Kelsheimer et al. 1953). The widespread distribution of these grasses makes them extremely important in the population dynamics of the FAW.

Resistance of bermudagrass, *Cynodon dactylon* (L.) Pers., to the FAW was first reported by Leuck et al. (1968) in Tifton 292 (P.I. 290884). In later studies, Leuck and Skinner (1970) found that mortality of FAW larvae and pupae was higher on Georgia accession No. 239 (P.I. 289931) than on 'Coastal.' Lynch et al. (1983) confirmed the high level of resistance in Tifton 292 in evaluations of 9 bermudagrass clones, reporting that the resistance was primarily antibiosis.

Pencoe and Martin (1981, 1982b) investigated FAW development on 15 grasses and sedges. Goosegrass, *Eleusine indica* (L.), and Coastal bermudagrass were found to be the most suitable hosts, while yellow nutsedge, *Cyperus esculentus* L., was the least suitable host, as measured by a host-suitability index. Multiple choice preference tests showed that goosegrass was most preferred of the grasses offered to 3rd-instar FAW larvae (Pencoe and Martin 1982a).

Centipedegrass, *Eremochola ophiuroides* (Munro) Hack., also has been identified as resistant to the FAW (Wiseman et al. 1982). Both non-preference and antibiosis mechanisms of resistance were found when centipedegrass was compared with Coastal bermudagrass and carpetgrass, *Axonopus affinis* Chase.

Chemical components in plants influence insect behavior in both food finding and food acceptance (Thorsteinson 1960). The chemicals may act as attractants, stimulants, repellents, or deterrents (Dethier et al. 1960) and influence insect behavior, including the preference or nonpreference mechanism of resistance as defined by Painter (1951). Numerous studies have been conducted for both chemical and non-chemical bases of food preference of lepidopterous larvae (Hedin et al. 1977). However, the FAW has

been studied less from an insect-plant relationship than many other economically important insect pests. This lack of information prompted a study on the FAW orientation and host preference mechanisms on several selected grasses.

Materials and Methods

Coastal, Tifton 10, and Tifton 292 (P.I. 290884) bermudagrasses, C-181 and common centipedegrass, and zoysiagrass (*Zoysia* sp.) were selected for this study. Plants of each grass were obtained from pure stands from the field and were subsequently maintained in a greenhouse for laboratory evaluations. FAW larvae used in the evaluation were obtained from a laboratory colony maintained at the Insect Biology and Population Management Research Laboratory (USDA-ARS, Tifton, GA) (Perkins 1979).

FAW Orientation: Orientation of FAW larvae to grass food sources was evaluated in an olfactometer constructed from two plastic rearing cups (4-cm diam, 4.5 cm high) connected with a 10-cm "Y-shaped" tube. Grass clippings (4 g/sample) were placed in one or both of the rearing cups and the cups were capped. Twenty neonate FAW larvae were then placed in the entrance of the "Y-shaped" tube with a camel-hair brush after which the tube was sealed with a cork. The olfactometer was covered with dark paper to avoid phototactic influences on larval orientation. The number of larvae reaching each rearing cup after 3 h was noted. Orientation comparisons included larval response to each individual grass vs. an empty cup and a one-on-one comparison of all grasses. Two replications with 5 olfactometers per replication of each comparison were conducted. Differences within each comparison were expressed in % FAW orienting to the respective stimuli. Data were evaluated with a t-test for paired comparisons.

Preference Tests: Two preference tests examined the responses of neonate FAW larvae to the 6 grasses. In the first test, larvae were presented a choice of all 6 grasses using the procedure described by Wiseman et al. (1982). Two leaf blades, each ca. 4.5 cm in length, were placed in a randomly paired fashion for each of six replications on moistened filter paper in the bottom of individual plastic dishes (25-cm diam.) prior to placing 25 neonate FAW into the center of the dish. Data were expressed as percentage of larvae on each grass.

The 2nd test with neonate larvae was conducted to present the larvae with a choice of only 2 of the 6 grasses in each comparison. Two leaf blades of each of 2 selected grasses were placed opposite each other in a 2.5-cm deep plastic feeding chamber 8 cm in diam. Five neonate FAW larvae were then placed in the center of each dish and sealed with a lid. Twenty-four replications with one dish per replication were used.

A 3rd test was conducted to examine the preference of older FAW larvae for the 6 grasses. As in the first test, 25-cm diam. dishes were used in the evaluation and procedures were identical with the exception that 10 leaves of each grass were placed randomly in the 6 equal sections marked on the filter paper. Then fifteen 3rd-instar larvae were placed in the center of each dish for 4 replications with 6 dishes per replication.

Dishes in all 3 preference tests were sealed, covered with dark paper to exclude light influence, and placed in an incubator operated at 26.7 ± 2°C and 70 ± 5% RH. The number of larvae on or under each grass

section was recorded after 12, 24, 36, and 48 h of infestation. Leaf damage was rated after 48 h on a 0-9 scale, where 0 = no damage and 9 = leaf totally consumed. The preference ratio was obtained by calculating the mean percentage of larvae on each grass at each observation. The data from all preference tests were transformed (arcsin $\sqrt{\%}$) and subjected to an analysis of variance. The means were separated by Duncan's multiple range test.

Results and Discussion

FAW Orientation: In all 6 tests, when larvae were presented a choice of a specified grass vs. an empty cup in the olfactometer, FAW orientation was significantly ($P < 0.05$) toward the grass (Table 1). These data indicate that chemoreception has an important role in host plant location by neonate FAW larvae.

When FAW larvae were presented a choice of 2 grasses, a significant ($P < 0.05$) difference in FAW orientation was noted in only 1 of the 15 paired comparisons. FAW larvae oriented toward Coastal bermudagrass significantly ($P < 0.05$) more often than they oriented toward zoysiagrass. These results indicate that either (1) the host plants released the same or similar volatile chemical(s), or (2) they released different volatile chemicals that induced an equivalent response in orienting larval movement toward the host plants.

Preference Tests: When larvae were presented with a choice of all 6 grasses in the 1st preference test, Tifton 10 and Coastal bermudagrass were preferred ($P < 0.05$) by FAW neonate larvae over Tifton 292 bermudagrass, C-181 centipedegrass, and zoysiagrass at 24, 36, and 48 h (Table 2). The results were expressed as a mean preference ratio ($\bar{x}$ % FAW on specific grass $\div$ $\bar{x}$ % FAW on least preferred grass), which indicates that Tifton 10 was the most preferred while zoysiagrass was the least preferred. The mean preference ratios closely paralleled damage ratings for the respective grasses. Tifton 10 bermudagrass sustained significantly ($P < 0.05$) more damage than any other grass, while zoysiagrass was among the least damaged (ca. 50-fold less than the damage sustained by Tifton 10).

Results of the paired comparisons of grasses (2nd preference test) confirmed the results of the 1st preference test. Tifton 10 bermudagrass was preferred (Table 3) over all other grasses in a one-on-one comparison.

TABLE 1. Orientation of neonate fall armyworm larvae toward plant material versus empty cups.[1]

Plant material	% FAW ($\bar{x}$ ± SE) orienting to		LSD
	Grass	Empty cup	(P = 0.05)
Coastal bermudagrass	81.5 ± 7.6	4.5 ± 2.7	8.65
Common centipedegrass	74.5 ± 14.5	19.0 ± 11.8	20.01
Tifton 10 bermudagrass	76.0 ± 5.8	16.5 ± 6.9	9.63
Tifton 292 bermudagrass	83.5 ± 9.2	12.5 ± 8.3	13.32
C-181 centipedegrass	82.0 ± 6.6	6.5 ± 3.3	7.87
Zoysiagrass	79.5 ± 8.2	9.5 ± 6.8	11.39

[1]Data based on 2 replications with 5 observations for each replication.

TABLE 2. DAMAGE RATINGS AND PREFERENCE OF FALL ARMYWORM LARVAE FOR 6 GRASSES.[1]

Grass	% FAW larvae on host grass post infestation (hr)				Mean preference ratio[2]	Damage rating[3]
	12	24	36	48		
Tifton 10 bermudagrass	20.7 a	21.7 a	16.4 a	9.7 a	10.6	4.8 a
Coastal bermudagrass	11.9 abc	12.5 b	10.8 b	9.3 a	7.0	2.0 b
Common centipedegrass	13.8 ab	7.4 bc	6.9 bc	7.4 ab	5.2	1.8 bc
C-181 centipedegrass	5.6 bc	3.9 c	4.9 cd	3.7 bc	2.8	0.6 bc
Tifton 292 bermudagrass	5.2 bc	3.3 c	2.5 cd	3.1 c	2.1	0.3 c
Zoysiagrass	2.9 c	1.3 c	1.5 d	1.3 c	1.0	0.1 c

[1]Means in a column not followed by the same letter are significantly different (P = 0.05) by Duncan's multiple range test.
[2]Mean preference ratio = Mean % FAW on specific grass/Mean % FAW on Zoysiagrass.
[3]Damage rating scale of 0 to 9, where 0 = no damage and 9 = leaf completely consumed.

TABLE 3. DAMAGE RATINGS AND PREFERENCE RESPONSES OF NEONATE FALL ARMYWORM LARVAE TO PAIRED COMPARISONS OF SELECTED GRASSES.[1]

Grass	Mean % FAW larvae on host plant				
	Tifton 10	Coastal	Centipede	C-181	Zoysia
Coastal	54.8 a	—	—	—	—
	21.9 b	—	—	—	—
Centipede	38.5 a	44.6 a	—	—	—
	22.8 b	13.6 b	—	—	—
C-181	46.6 a	47.3 a	30.9 a	—	—
	6.6 b	11.6 b	17.1 b	—	—
Zoysia	29.6 a	28.3 a	39.1 a	43.0 a	—
	4.8 b	8.9 b	2.5 b	5.0 b	—
Tifton 292	47.6 a	51.2 a	36.8 a	40.0 a	31.5 a
	3.8 b	7.0 b	5.0 b	35.1 a	3.3 b

[1]Means within a column for each comparison not followed by the same letter are significantly different ($P = 0.05$) by Duncan's multiple range test. For each comparison, the upper mean relates to the grass in the upper column and the lower mean refers to the grass in the left margin.

Coastal bermudagrass was more preferred and had a significantly higher damage rating than common centipedegrass, thus confirming results reported by Wiseman et al. (1982). Coastal bermudagrass also was preferred over C-181 centipedegrass, zoysiagrass, and Tifton 292 bermudagrass. Common centipedegrass was preferred over C-181, Tifton 292 bermudagrass, and zoysiagrass. Among the nonpreferred grasses, C-181, Tifton 292 bermudagrass, and zoysiagrass, zoysiagrass was the least preferred, again demonstrating the high level of resistance discovered in this grass species.

Based on damage ratings and larval preference ratios, common centipedegrass was more preferred than C-181, Tifton 292 bermudagrass, or zoysiagrass. However, there was no significant difference in the damage rating between C-181 and common centipedegrass. Zoysiagrass was preferred less than C-181 and Tifton 292 bermudagrass. However, differences between the damage ratings of the least preferred grasses, such as C-181 centipedegrass (0.9) vs. Tifton 292 bermudagrass (0.5) and Tifton 292 bermudagrass (0.4) vs. zoysiagrass (0.1), were more difficult to determine since the damages were very negligible. The damage ratings were not significant and did not reflect feeding differences. Results were also confounded by high mortality during the tests that compared Tifton 292 bermudagrass and zoysiagrass.

Preferences of 3rd-instar FAW larvae for the various grasses (Table 4) were similar to those exhibited by neonate larvae. Tifton 10 bermudagrass was the most highly preferred at 12, 24, and 36 h, had the highest mean preference ratio, and sustained the most damage of all grasses examined, while Tifton 292 bermudagrass and zoysiagrass were among the least preferred. Thus, FAW larval age had little influence on host plant preference.

In comparing results of all 3 preference tests, the 6 grasses can be ranked in their order of preference by FAW larvae as follows: Tifton 10 bermudagrass is highly preferred; Coastal bermudagrass is moderately preferred;

TABLE 4. PREFERENCE OF 3RD-INSTAR FALL ARMYWORM LARVAE FOR 6 GRASSES.[1]

Grass	% FAW larvae on host grass post infestation (hr)				Mean preference ratio[2]	Damage rating[3]
	12	24	36	48		
Tifton 10 bermudagrass	35.9 a	11.7 a	20.0 a	6.6 ab	9.1	8.2 a
Coastal bermudagrass	15.0 b	5.9 bc	11.9 b	10.4 a	5.3	4.9 b
Common centipedegrass	15.5 b	8.6 ab	10.3 b	7.1 ab	5.1	3.3 c
C-181 centipedegrass	6.9 c	4.2 c	7.3 b	5.9 bc	3.0	1.3 d
Tifton 292 bermudagrass	2.8 c	1.7 d	2.2 c	1.5 d	1.0	0.3 d
Zoysiagrass	2.2 c	5.0 c	2.5 c	3.3 cd	1.6	0.3 d

[1]Means in a column not followed by the same letter are significantly different (P = 0.05) by Duncan's multiple range test.
[2]Mean preference ratio = Mean % FAW on specific grass/Mean % FAW on Tifton 292 bermudagrass.
[3]Damage rating scale of 0 to 9, where 0 = no damage and 9 = leaf completely consumed.

common and C-181 centipedegrass are moderately nonpreferred; Tifton 292 bermudagrass and zoysiagrass are highly nonpreferred. Our results demonstrate that nonpreference, in addition to antibiosis (Lynch et al. 1983), is also a component of the resistance of Tifton 292 bermudagrass to the FAW.

Earlier studies have shown that Coastal bermudagrass (Leuck and Skinner 1970) and Tifton 10 bermudagrass are susceptible to FAW feeding, while centipedegrass (Wiseman et al. 1982), zoysiagrass (unpublished), and Tifton 292 bermudagrass (Leuck et al. 1968, Lynch et al. 1983) are resistant. However, as our studies have indicated, the preference or nonpreference for these grasses as host plants occurred only after FAW larvae perceived the presence of the grass through chemoreception, moved toward the grass, and began feeding.

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A NATURAL DECLINE OF PESTIFEROUS CHIRONOMIDAE (DIPTERA) POPULATIONS FROM 1979 TO 1984 IN AN URBAN AREA OF CENTRAL FLORIDA

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ABSTRACT

The population trends of chironomid larvae in Lake Monroe in central Florida and the occurrence of adult midges around residences and businesses along the southern shore of the lake in Seminole County were studied from January 1979 to July 1984. *Glyptotendipes paripes* Edwards and *Chironomus crassicaudatus* Malloch were the predominant species as larvae and as adults. Larval densities (Ekman dredge samples) of *G. paripes* and *C. crassicaudatus* fluctuated between <1 and >6000 and <1 and ca. 1800/m^2, respectively. The density of total midge larvae was the highest (ca. 7000/m^2) in August 1979 and the lowest (100/m^2) in July 1982. There was a decline of 80% of total larvae in the lake in 1983 as compared to 1979. In New Jersey light trap collections, *G. paripes* was the predominant species (>70%) in 1980. It was outnumbered by *C. crassicaudatus* (60% of all midges) in 1981 and 1982. In 1983, populations of *G. paripes* returned to 63% while *C. crassicaudatus* declined to 6% of the total adults. Peaks of adult emergence usually occurred from May to November when in some catches >500,000 adult midges were taken in a trap in 1 night. There was a considerable reduction (up to 93%) of adult midges in the study area from 1981 to 1984. This reduction was primarily due to the lower number of *G. paripes* and *C. crassicaudatus*.

RESUMEN

De Enero 1979 a Julio 1984 se estudió la tendencia de poblaciones de las larvas "chironomid" en el lago Monroe en el Condado de Seminole en el centro de la Florida, y la ocurrencia de estas moscas enanas adultas alrededor de residencias y negocios a lo largo de la orilla sur del lago. *Glyptotendipes paripes* Malloch, fueron las especies predominantes como larvas y adultos. La densidad de las larvas (muestras de draga Ekmar) *G. paripes* y *C. crassiccaudatus* fluctuó entre <1 y >6000, y <1 y approx. 1800/m^2 respectivamente. La densidad total de larvas fue más alta (approx. 7000/m^2 en Agosto de 1979 y más baja (100/m^2) en Julio de 1982. Hubo una reducción de un 80% del total de larvas en el lago en 1983 cuando se compara con 1979. *G. paripes* fue la especie predominante (>70%) colectada en trampas de luz tipo New Jersey en 1980. Estos números fueron excedidos por *C. crassicaudatus* (60% de todas las moscas enanas) en 1981. En 1983, poblaciones de *G. paripes* volvio a 63% mientras que *C. crassicaudatus* bajó un 6% del total de los adultos. La salida mas grande de los adultos usualmente fue de Mayo a Noviembre, cuando algunas capturas fueron >500,000 adultos en una trampa en una noche. Hubo una reduccion considerable (hasta un 93%) de adultos enanos en el año estudiado de 1981 a 1984. Estas reducciones fueron principalmente debidas al bajo número de *G. paripes* y *C. crasicaudatus*.

Non-biting aquatic midges (Diptera:Chironomidae) frequently emerge in phenomenal numbers from a variety of habitats. In many parts of the world massive swarms of midges are a serious nuisance to man and livestock because they restrict outdoor activity and, in extreme cases, may cause asphyxia (Cranston et al. 1983). Ali (1980) gave details of the nature of nuisance and economic problems caused by adult midges. Apart from the nuisance and economic problems, Cranston et al. (1981) reported the association of seasonal midge emergence from the Nile in Sudan with human allergic reactions, such as asthma and allergic rhinitis. It is now believed that chironomids are more than a local Sudanese problem, and are potentially a worldwide cause of allergy (Cranston et al. 1983).

In the last decade, the City of Sanford in central Florida frequently experienced massive emergences of midges primarily from the adjacent Lake Monroe. In 1977, a "blind mosquito" task force study undertaken by the Greater Sanford Chamber of Commerce revealed that at least 10 counties of Florida have midge problems and that Sanford alone suffers an annual economic loss of 3-4 million dollars. This paper reports population trends of chironomid larvae in Lake Monroe from January 1979 to July 1984, and the occurrence of adult midges around Sanford waterfront businesses and residences from January 1980 to July 1984.

Materials and Methods

Lake Monroe is in Seminole and Volusia counties of central Florida. The St. Johns River is the lake water source as well as discharge. The lake is ca. 8.5 km long and 6.0 km wide at its widest point. It has a surface area of ca. 4000 ha and a 20 km shoreline. Water in Lake Monroe remains turbid throughout the year and ranges in depth from <1 m at the perimeter to 3.0 m in some central portions. Sediments in the lake are primarily mud, sand, and fine silt. The City of Sanford borders the lake along the southern 5-6 km shoreline.

Twenty stations in the lake, established and marked for sampling midge larvae, were reported in a previous study by Ali and Baggs (1982). The larval samples were collected biweekly from January 1979 to March 1981, monthly from April 1981 to April 1982, and bimonthly or quarterly from May 1982 to July 1984. A minimum of 3 samples of benthic mud was taken at each station by using a 15x15x30 cm Ekman dredge. Each sample was washed and processed as described in Mulla et al. (1971). The processed samples were examined in the laboratory by the method of Ali et al. (1977), and midge larvae were identified and counted. At the time of sampling, measurements of water temperature at surface and bottom of the lake were taken at each station by using a YSI meter (Model 54-A, Yellow Springs Instrument Co., OH). The daily air temperature data were obtained from a nearby permanent recording station maintained at the Central Florida Research and Education Center of the University of Florida.

Four New Jersey light traps were used to study the prevalence of adult midges. Each trap was fitted with a 60-watt bulb and a photoelectric switch. The traps were placed 1-2 km apart on premises of waterfront businesses and residences in Sanford along the southern 5-6 km shore of Lake Monroe. The traps were hung 2-3 m above ground level. Adult midges

were collected daily from each trap from January 1980 to July 1984, except for the weekends when a 3 nights' catch was taken every Monday. Also, on some holidays, the adults accumulated for 2-4 days. In the laboratory, adult midges in each sample were segregated into species or genera and counted. Samples containing large numbers (>50,000 adults/trap/night) were subsampled by weight but at least 1/16th portion of the large samples was completely counted and taxonomically determined.

Results and Discussion

Species Composition. Among Chironomini, *Glyptotendipes paripes* Edwards, *Chironomus crassicaudatus* Malloch, *Chironomus decorus* Johannsen, *Chironomus* sp., *Parachironomus* sp., *Goeldichironomus carus* (Townes), *Goeldichironomus holoprasinus* (Goeldi), *Cryptochironomus fulvus* Johannsen, and *Polypedilum halterale* (Coquillett) occurred in the larval and adult collections. The Tanytarsini were represented by several species of *Tanytarsus* and *Rheotanytarsus*. The Tanypodinae were comprised of *Coelotanypus concinnus* (Coquillett), *Coelotanypus scapularis* (Loew), and *Procladius sublettei* Roback. The Orthocladiinae were represented by species of *Cricotopus*. A few other chironomid species of minor quantitative importance in the study area also occurred in the collections.

Larval Populations. Population trends of midge larvae, water temperature in Lake Monroe, and air temperature near the study area, covering the period from January 1979 to July 1984 are shown in Fig. 1. Among all midge species, *G. paripes* and *C. crassicaudatus* were quantitatively important. It was not possible to separate 1st and 2nd instars of *Chironomus* spp. (particularly *C. crassicaudatus* and *C. decorus*) into species due to taxonomic difficulties, therefore, all were included in *C. crassicaudatus*. *Glyptotendipes paripes* and *C. crassicaudatus* formed 87% of the total chironomid larvae in the lake in 1979. Their populations comprised 31-82% of the total chironomids in the subsequent years. In 1983, the 2 species totaled 31% of the total midge larvae. Each year, the larval populations generally increased during the spring and summer seasons when the air and water temperatures increased. The larval populations decreased during the autumn and winter months with the decreasing air and water temperatures (Fig. 1). The highest mean density of *G. paripes* (>6000 larvae/m^2) was recorded in August 1979. In subsequent years, *G. paripes* decreased considerably and fluctuated from <1 to 80 larvae/m^2 in the periodic collections. From 1980 to 1983, the mean larval density of *G. paripes* did not exceed 80/m^2 even during the summer months. In contrast to *G. paripes*, *C. crassicaudatus* gradually increased and predominated in the lake from 1980 to 1983. *Chironomus crassicaudatus* achieved the highest mean density (ca. 1800 larvae/m^2) in June 1980. Larvae of Tanypodinae (mostly *C. concinnus* and *P. freemani*) did not show pronounced seasonal trends. Tanypodinae fluctuated from 20 to 500 larvae/m^2 during the sampling period and formed from 12% of the total chironomids in 1979 to 56% in 1983. The highest density of total chironomid larvae in the lake existed in 1979 when ca. 7000 larvae/m^2 were taken. In subsequent years, the total density fluctuated between 110 and 1700/m^2. There was a decline of 80% of total midge larvae in the lake in 1983 as compared to 1979 and this was mainly due to the population reductions of *G. paripes* and to an extent, *C. crassicaudatus*. The trend of the larval decline in the lake continued in 1984.

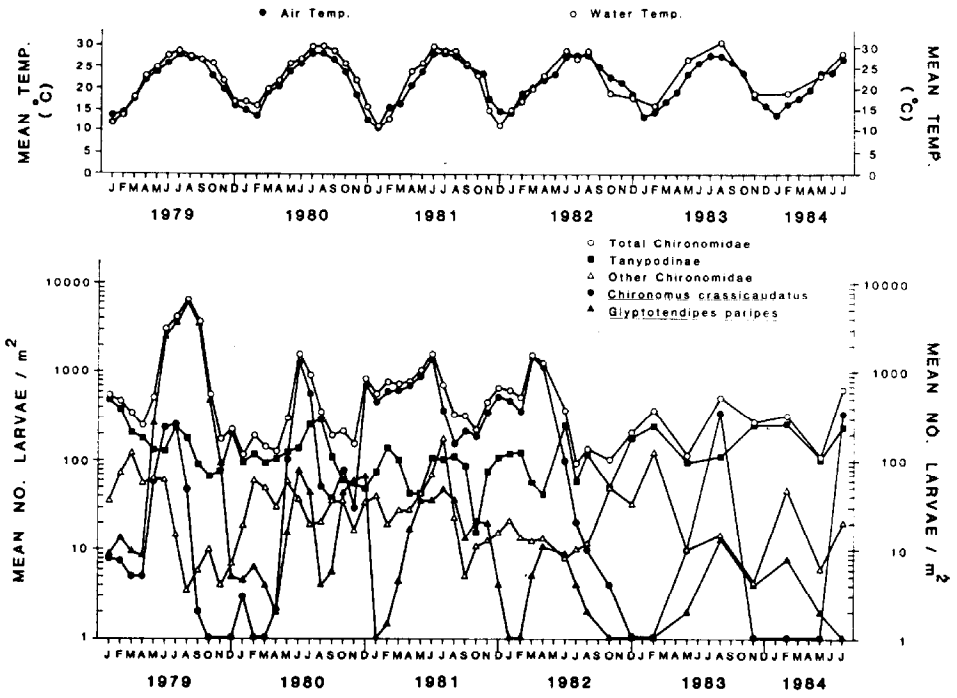

Fig. 1. Population trends of chironomid midge larvae in Lake Monroe, Seminole and Volusia Counties, FL (January 1979-July 1984). The water temperature represents the daytime mean of surface and bottom temperatures taken periodically at 16-20 larval sampling stations in the lake. The air temperature is the monthly average of the mean of daily maximum and minimum temperatures recorded near the study area.

Adult Populations. Figure 2 shows the monthly population changes of adult chironomids along lakefront Sanford from January 1980 to July 1984; the seasonal trends are summarized in Table 1. *Glyptotendipes paripes* was the predominant species (>70%) taken in the light traps in 1980. However, in 1981, *C. crassicaudatus* outnumbered *G. paripes* (Table 1). In 1982, *C. crassicaudatus* remained the most numerous (60%) of all midges while *G. paripes* declined to levels of <1% of the total adults. In the following year, populations of *G. paripes* returned to 63% of the total adults while those of *C. crassicaudatus* decreased to 6% of the total adults. The annual mean percent composition of Tanypodinae during the study period fluctuated between 5 and 15% of the total adults. Other Chironomidae (predominantly *C. fulvus*, *P. halterale*, and *Tanytarsus* spp.) formed <1 to 21% of the total adults taken annually from 1980 to 1983 but in the winter and spring of 1984, they predominated in the collections. Each year, adult populations of all midge species remained very low during the winter months, gradually increasing in March-April and thereafter attaining several peaks from May to November when the air temperatures and the water temperatures in Lake Monroe generally remained above 18°C (Fig. 2). In the warmer periods, the number of total adults taken daily in a trap varied considerably, ranging from 0 to >500,000. A comparison of total adults taken each year shows considerable reductions (up to 93%) of adult midges at lakefront Sanford from 1981 to 1984. These reductions were primarily due to the lower numbers of *G. paripes* and *C. crassicaudatus*.

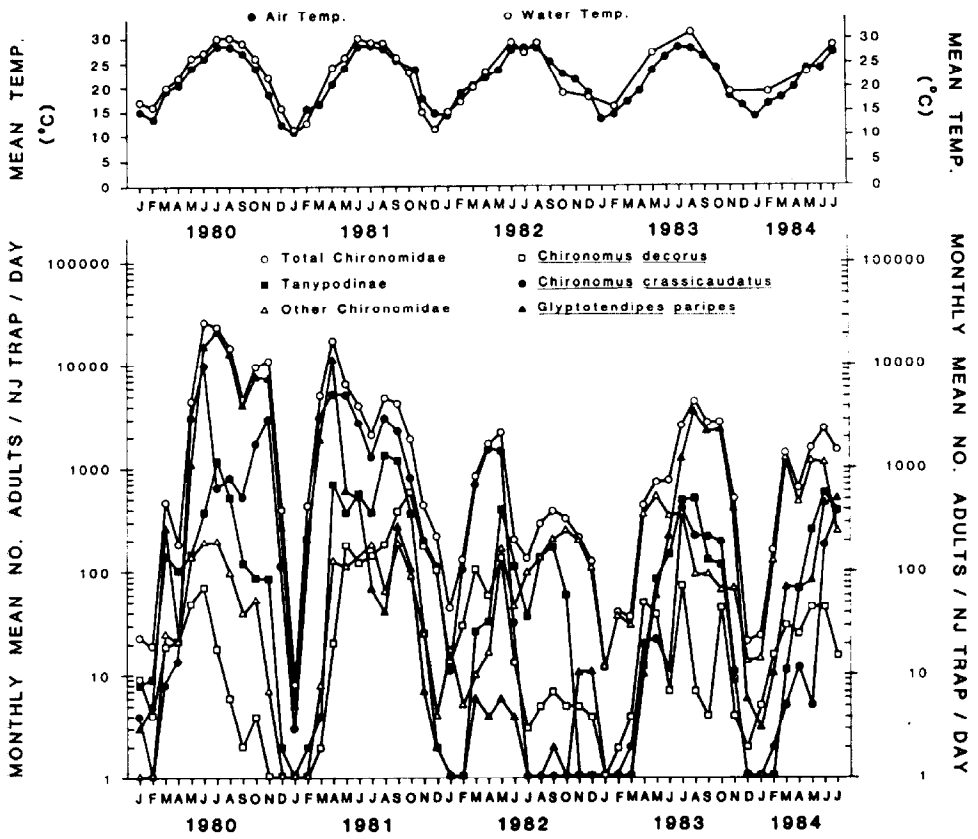

Fig. 2. Monthly distribution of adult chironomid midges occurring in New Jersey light traps located along lakefront, Lake Monroe, Sanford, FL (January 1980-July 1984). Explanation for air and water temperatures are the same as in Fig. 1.

The quantitative composition of populations of midge species may change from year to year under the influence of a number of intrinsic and extrinsic factors. Among these factors, temperature is regarded as the most obvious, affecting seasonal cycles and abundance of aquatic insects including chironomids (Ali et al. 1977, Elliott 1967). Other factors, such as the availability of phytoplankton and zooplankton (midge food), the nature and intensity of local oviposition, extent of natural enemies, competition for food and space, and the prevailing chemical conditions may also significantly influence the seasonal quantitative differences of midge species.

This long-term study clearly indicates that *G. paripes* and *C. crassicaudatus*, and to a lesser extent *C. decorus* are the primary pest species of midges in the Sanford area and are permanent inhabitants of Lake Monroe. The periodic abundance of adults of these species in Sanford generally corresponded with their prevailing high larval densities in the lake. Tanypodinae and other Chironomidae, such as *P. halterale*, *C. fulvus*, and *Tanytarsus* spp., at times, comprise significant numerical proportions of the total adults. However, these midges due to their smaller adult size than *G. paripes*, *C. crassicaudatus*, and *C. decorus* are less noticeable and may not be considered as pestiferous at the levels of emergence recorded during the 5 years of this investigation.

TABLE 1. SEASONAL OCCURRENCE OF ADULT CHIRONOMIDS IN NEW JERSEY LIGHT TRAPS PLACED AT BUSINESS AND RESIDENTIAL LOCATIONS ALONG SOUTHERN PERIPHERY OF LAKE MONROE, SANFORD, FLORIDA (1980-1984).

Species	Mean no. (±SD) adults/trap/day in seasons				Annual mean[a] (±SD)
	Winter	Spring	Summer	Autumn	
			1980		
Glyptotendipes paripes	94 ± 156	5644 ± 8814	12996 ± 8595	5227 ± 4292	5990 ± 7346
Chironomus crassicaudatus	4 ± 4	4354 ± 5064	664 ± 154	1663 ± 1484	1671 ± 2840
Chironomus decorus[b]	11 ± 8	65 ± 45	9 ± 10	1 ± 2	21 ± 33
Tanypodinae	69 ± 105	330 ± 268	1173 ± 1084	83 ± 70	414 ± 672
Other Chironomidae[c]	9 ± 7	122 ± 107	114 ± 109	21 ± 16	67 ± 40
			1981		
Glyptotendipes paripes	702 ± 1036	4188 ± 6298	130 ± 133	40 ± 61	1265 ± 3254
Chironomus crassicaudatus	1151 ± 1803	4525 ± 1502	2295 ± 910	382 ± 391	2088 ± 1961
Chironomus decorus[b]	1 ± 1	145 ± 97	329 ± 166	376 ± 397	213 ± 245
Tanypodinae	2 ± 2	951 ± 530	1398 ± 674	222 ± 324	643 ± 703
Other Chironomidae[c]	1 ± 1	129 ± 84	145 ± 100	46 ± 40	80 ± 93
			1982		
Glyptotendipes paripes	3 ± 3	5 ± 1	1 ± 1	8 ± 6	4 ± 4
Chironomus crassicaudatus	272 ± 375	1084 ± 912	<1	1 ± 1	340 ± 626
Chironomus decorus[b]	51 ± 51	73 ± 68	5 ± 2	5 ± 1	34 ± 48
Tanypodinae	9 ± 16	187 ± 195	120 ± 74	20 ± 34	84 ± 119
Other Chironomidae[c]	11 ± 7	78 ± 82	151 ± 55	196 ± 81	109 ± 81
			1983		
Glyptotendipes paripes	<1	100 ± 114	2434 ± 1179	937 ± 1286	868 ± 1262
Chironomus crassicaudatus	1 ± 1	19 ± 7	223 ± 197	69 ± 110	78 ± 138
Chironomus decorus[b]	2 ± 2	32 ± 23	29 ± 40	17 ± 24	20 ± 25
Tanypodinae	<1	83 ± 69	377 ± 210	43 ± 67	126 ± 183
Other Chironomidae[c]	27 ± 13	418 ± 102	188 ± 163	50 ± 31	283 ± 276

TABLE 1. (Continued)

Species	Mean no. (±SD) adults/trap/day in seasons				Annual mean[a] (±SD)
	Winter	Spring	Summer	Autumn	
		1984[d]			
Glyptotendipes paripes	28 ± 37	38 ± 42			33 ± 5
Chironomus crassicaudatus	2 ± 2	9 ± 5			6 ± 3
Chironomus decorus[b]	17 ± 13	35 ± 15			26 ± 10
Tanypodinae	4 ± 6	167 ± 139			86 ± 103
Other Chironomidae[c]	480 ± 689	828 ± 488			654 ± 326

[a]Annual mean represents the mean number of adults occuring per trap per day of a year.
[b]Includes some *Goeldichironomus carus*, *Chironomus* sp., and *Parachironomus* sp.
[c]Mostly *Cryptochironomus fulvus*, *Polypedilum halterale*, *Goeldichironomus holoprasinus*, *Tanytarsus* spp., *Rheotanytarsus* spp., and *Cricotopus* spp.
[d]The annual mean of 1984 represents the mean number of adults occurring per trap per day from January 1 to June 30, 1984.

The quantitative threshold of tolerance level of adult midges by the residents of Sanford area is not known. However, the reduced levels of midge emergence and prevalence during 1982 to 1984 can be considered tolerable because in this period no articles concerning the midge problem appeared in the local newspapers and also no significant complaints (telephone calls) from Sanford lakefront residents and business owners, usually affected by midge swarms, were received by the University of Florida's Central Florida Research and Education Center (CFREC) at Sanford. In contrast, during the warmer months of 1979 and 1980, at least 2 articles on the midge problem had appeared each year in the local newspapers and at least 2-3 telephone calls from midge affected personnel were received every week at the CFREC-Sanford during the 2 years.

Endnote

Florida Agricultural Experiment Stations Journal Series No. 5810.

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COMPARATIVE TOXICITIES OF SYNTHETIC PYRETHROIDS TO THE FALL ARMYWORM, *SPODOPTERA FRUGIPERDA*

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ABSTRACT

Nine synthetic pyrethroids were tested in the laboratory for toxicity to third and sixth instar fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae). LD_{50} values for 3rd instar FAW ranged from 0.0041 μg/insect (permethrin [FMC]) to 0.1558 μg/insect (Ammo®). All pyrethroids were more toxic than diazinon. LD_{50} values for 6th instar ranged from 0.213 μg/insect (permethrin [FMC]) to 5.841 μg/insect (Ammo®). Ammo® was the only pyrethroid less toxic than diazinon to 6th instar.

RESUMEN

Se evaluaron en el laboratorio nueve pyrethroids para toxicidad hacia el tercer y sexto estadio del cogollero, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae). Valores de LD_{50} para el 3er. estadio del cogollero varió de 0.0041 μg/insecto (permethrin (FMC)) a 0.1558 μg/insecto (Ammo®). Todos los pyrethroids fueron más tóxicos que diazinon. Los valores de LD_{50} para el 6to. estadio varió de 0.213 μg/insecto (permethrin [FMC], a 5.841 μg/insecto (Ammo®). Ammo® fue el único pyrethroid menos toxico que diazinon hacia el 6to. estadio.

The synthetic pyrethroids, first described in 1973, have been cited for their potential as agricultural pest control agents (Breese 1977, Elliott et al. 1978, Hall 1979, Harris and Svec 1976, Schmidt et al. 1976). The degree of control of the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), one of the most important insect pests in the southeast United States, (Fuxa 1982, Mitchell 1979), with the synthetic pyrethroids has varied. Bass (1978) reported poor control in peanuts with Ambush® and Pydrin® and unacceptable control on grain sorghum from Pounce®, Pydrin®, and FMC 45498. However, Wood et al. (1981) found permethrin to be more toxic than methyl parathion, trichlorfon, or carbaryl to FAW larvae reared on various diets.

The purpose of this study was to evaluate contact toxicities of 9 synthetic pyrethroids to a laboratory strain of FAW.

MATERIALS AND METHODS

Larvae used in contact toxicity tests were from a laboratory reared

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colony established in February 1982 with pupae obtained from the Southern Grain Insects Research Laboratory in Tifton, Georgia. The insects were reared on artificial diet (Bio-Serv Corn Earworm Rearing Media, Bio-Mix #9394) according to a procedure modified from Perkins (1979).

One liter of insecticide-acetone (wt/vol) solution was applied to the dorsal thoracic region of 3rd or 6th instars with a syringe microburet. Larvae were placed into individual 5 cm diam petri dishes and allowed to feed on artificial diet. Larvae were maintained in environmental chambers at 27° ± 2°C, 14:10 L:D, and 60-70% RH. Mortality, determined by failure to respond to probing, was recorded at 24 h.

Preliminary dosages of insecticides were used to establish mortality ranges. Dosages-mortality regression lines, obtained by probit analysis (Finney 1964), provided LD_{50} values, confidence intervals, LD_{90} values, and slopes for each insecticide for 5-10 dose levels using a minimum of 30 larvae/dose. A toxicity index (Sun 1950) was used to compare the toxicity of each synthetic pyrethroid with that of diazinon, an organophosphate used as a standard.

The synthetic pyrethroids were technical formulations of permethrin and cypermethrin (ICI Americas, Inc.); permethrin, cypermethrin, Pounce®, and Ammo® (FMC Agricultural Chemical Group); Pydrin® (Shell Development Co.); Mavrik® (Zoecon Corp.); and Pay-Off® (American Cyanamid Co.).

Results and Discussion

The pyrethroids were 3 to 120 times more toxic than diazinon to 3rd instar (Table 1). LD_{50} values ranged from 0.1558 μg/insect (Ammo®) to 0.0041 μg/insect (permethrin [FMC]), representing a 38-fold decrease in concentration. Relatively flat regression lines for Pydrin®, cypermethrin (ICI), and Ammo® suggest heterogenous responses (Hoskins and Gordan 1956), indicating a possible tolerance to those insecticides by portions of the population.

The synthetic pyrethroids, with the exception of Ammo®, were also effective contact insecticides to 6th instar FAW (Table 2). LD_{50} values ranged from 5.841 μg/insect (Ammo®) to 0.213 μg/insect (permethrin

TABLE 1. Comparative toxicities of nine synthetic pyrethroids to laboratory-reared 3rd instar fall armyworm.

Compound	LD_{50} μg/insect	LD_{50} C.L.	LD_{90} μg/insect	slope	Toxicity index
permethrin (FMC)	0.0041	0.0036-0.0045	0.0102	3.82	11,968
permethrin (ICI)	0.0067	0.0062-0.0071	0.0110	5.67	7,324
Pounce®	0.0271	0.0178-0.0354	0.0590	3.10	1,811
cypermethrin (FMC)	0.0307	0.0104-0.0407	0.1053	2.73	1,598
Pay-Off®	0.0407	0.0275-0.0696	0.1215	2.70	1,207
Mavrik®	0.0487	0.0309-0.0507	0.0776	4.74	1,008
Pydrin®	0.1277	0.0712-0.1701	0.5808	1.95	384
cypermethrin (ICI)	0.1327	0.1301-0.2104	0.9445	1.69	370
Ammo®	0.1558	0.1390-0.2291	0.9339	1.71	315
diazinon	0.4907	0.4883-0.5158	1.0321	2.87	100

TABLE 2. COMPARATIVE TOXICITIES OF NINE SYNTHETIC PYRETHROIDS TO LABORATORY REARED 6TH INSTAR FALL ARMYWORM.

Compound	LD_{50}		LD_{90}		Toxicity
	μg/insect	C.L.	μg/insect	slope	index
permethrin (FMC)	0.213	0.200-0.372	0.561	2.49	1,820
cypermethrin (FMC)	0.250	0.187-0.687	0.788	2.87	1,550
Pay-Off®	0.306	0.190-0.385	0.978	2.78	1,267
permethrin (ICI)	0.662	0.649-0.706	1.122	5.23	585
cypermethrin (ICI)	0.684	0.501-0.882	1.289	5.50	567
Pydrin®	0.813	0.524-1.214	1.574	5.26	477
Mavrik®	1.456	0.340-1.657	7.435	2.83	266
Pounce®	3.471	2.044-4.202	7.100	4.20	112
Ammo®	5.841	5.204-6.582	11.847	3.91	66
diazinon	3.876	3.477-4.000	10.980	4.63	100

[FMC]), a 27-fold decrease in concentration. The pyrethroids, except Pounce® and Ammo® were from 2.5 to 18 times more toxic than diazinon to 6th instar. Pounce® had approximately the same toxicity as diazinon, and Ammo® was approximately 0.67 as toxic as diazinon. All pyrethroids had relatively steep regression lines indicating a homogenous response. This is a characteristic for insect populations that have not been exposed to any significant chemical selection pressure which allows a buildup of tolerance to the toxicant (Hoskins 1960).

Third instar larvae were more susceptible to the pyrethroids than were 6th instar. Differences in susceptibility ranged from 5X (cypermethrin [ICI]) to 128X (Pounce®). Diazinon was ca. 8X more toxic to 3rd instar than to 6th instar.

Within 10 min after treatment with pyrethroids at any concentration larvae displayed symptoms of pyrethroid poisoning (Ford et al. 1977), including initial hyperactivity, fluid loss due to regurgitation and eversion of the rectum, loss of coordination, knockdown leading to paralysis, and death. These reactions to poisoning may provide additional protection to plants by dislodging surviving insects and/or exposing them to increased predation. Water loss may also contribute to mortality, especially in hot summer weather.

McDonald (1979) found pyrethroids in general to be more toxic than organophosphates to the army cutworm. In this study, the pyrethroids were found to be more toxic than diazinon to FAW larvae even though the modes of action of the two insecticide classes are thought to be similar. Synthetic pyrethroids are better contact poisons than oral poisons (McDonald 1976), possibly because of their feeding deterrent properties (Gist and Pless 1985) which cause the insect to avoid ingesting the toxin.

The difference in toxicities of the pyrethroids in the laboratory vs the field can be partially explained by the absence of selective pressure in the laboratory population, demonstrated by the relatively steep dosage-mortality lines. Variation in toxicities to FAW has been explained on the basis of insect resistance (Farnham and Sawicki 1976), tolerance, cross resistance (Crowder et al. 1979, Twine and Reynolds 1980), and differences in the host crop (Wood et al. 1981). Because susceptibility of FAW to in-

secticides varies with the crop upon which they are feeding (Wood et al. 1981), additional field evaluations are needed to correlate efficacy in the field with that in the laboratory.

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SYNERGISTIC ACTIVITY OF PIPERONYL BUTOXIDE WITH NINE SYNTHETIC PYRETHROIDS AGAINST THE FALL ARMYWORM, *SPODOPTERA FRUGIPERDA*

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ABSTRACT

Nine synthetic pyrethroids were evaluated in the laboratory for synergistic activity with piperonly butoxide (1:8) when used on fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae). The cypermethrins (FMC Agricultural Chemical Group and ICI Americas, Inc.) were the only pyrethroids to have significant (Synergistic Ratio = 3.531 and 6.328 respectively) synergistic activity to eggs. Cypermethrin (FMC) (SR = 3.0700) and Ammo® (SR = 9.1111) were significantly synergized for 3rd instar. Ammo® (SR = 8.641) was significantly synergized for 6th instar.

RESUMEN

Se evaluaron en el laboratorio nueve pyrethroids sintéticos para actividades sinergéticas con piperonyl butoxide (1:8) cuando se usaron contra el cogollero, *Sodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae). Los cypermethrins (FMC Agricultural Chemical Group and ICI Americas, Inc.) eran los únicos pyrethroids que tuvieron una significante actividad sinergética hacia los huevos (una proporción sinergética = 3.531 y 6.328 respectivamente). Cypermethrin (FMC) (Reacción Sinergética = 3.0700) y Ammo® (Reacción Sinergética = 9.1111) fue significantemente sinergético hacia el 3er. estadio. Ammo® (Reacción Sinergética = 8.641) fue significantemente sinergético hacia el 6to. estadio.

Insecticidal synergism can be defined as increased activity (of an insecticide) resulting from the effect of one chemical on another. The first commercial synergist was introduced in 1940 to increase the effectiveness of the botanical insecticide, pyrethrum. Since that time it has been well established that synergists increase the effectiveness of pyrethroids by reducing their rate of metabolism in insects (Casida 1970, Jao and Casida 1974a,b, Yamamoto 1973).

The optimal synergist varies with the insect species and pyrethroid (Jao and Casida 1974a) as well as the stage of the insect's development. Yu (1983) pointed out that activities of various detoxifying enzymes fluctuate during the life stages of insects, thus low activity of these enzymes would indicate a susceptible period and vice versa. Piperonyl butoxide (PB), an oxidase inhibitor is the most commonly used synergist, although reports of

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activity have varied (Casida 1970, Chang and Jordan 1982, 1983, Jao and Casida 1974a, Lloyd and Ruczkowski 1980).

The purpose of this study was to evaluate the synergistic activity of piperonyl butoxide with 9 synthetic pyrethroids to a laboratory strain of fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith).

Materials and Methods

Procedures for ovicidal tests have been previously reported (Gist and Pless 1985b). Briefly, egg masses were treated by dipping them into acetone solutions of insecticide: PB. Each treatment was applied to 75-100 eggs and replicated 3 times. Eggs which hatched were counted daily for 7 days.

Larvae were reared and treated according to procedures detailed previously (Gist and Pless 1985a). Third and 6th instars were treated with 1 μl applications of insecticide: PB. Each treatment was applied to 3 replicates of 10 larvae/instar. Mortality was determined after 24h.

Insecticide-acetone (wt/vol):synergist-acetone (wt/vol) (1:8) solutions were tested. Preliminary dosages of insecticide:synergist solutions were used to establish mortality ranges. Dosage-mortality regression lines, obtained by probit analysis (Finney 1964) provided LC_{50} or LD_{50} values for each insecticide:synergist solution for 5-10 dose levels. Synergistic ratios (LC_{50} or LD_{50} of pyrethroid alone/LC_{50} or LD_{50} of pyrethroid + synergist) were established with LC_{50} or LD_{50} values from Gist and Pless (1985a,b). The Mann-Whitney U Test was used to determine significance of synergised vs. nonsynergised comparisons.

Synthetic pyrethroids used in this study were technical formulations of permethrin and cypermehtrin (ICI Americas, Inc.); permethrin, cypermethrin, Pounce®, and Ammo® (FMC Agricultural Chemical Group); Pydrin® (Shell Development Co.); Mavrik® (Zoecon Corp.); and Pay-Off® (American Cyanamide Co.). The synergist used was Prentox PBO 8® (91.3% technical piperonyl butoxide) (Prentiss Drug and Chemical Co., Inc.).

Results and Discussion

The pyrethroids were not readily synergised by PB when applied to FAW (Table 1). The only pyrethroids to have synergistic activity on eggs were cypermethrin (FMC) (SR $\cong$ 3.5) and cypermethrin (ICI) (SR $\cong$ 6.3). Cypermethrin (FMC) (SR $\cong$ 3.1) and Ammo® (SR $\cong$ 9.1) had synergistic activity on 3rd instar. Ammo® (SR $\cong$ 8.6) was the only pyrethroid to have synergistic activity on 6th instar. All of the above synergistic ratios are in the low to slightly moderate range of synergism.

For metabolic research, synergism is usually investigated by applying a synergist followed by an application of the active insecticide (Elliot and Janes 1978). This method would not be practical in field situations; therefore, it was not used in this study.

The cypermethrins (ICI, FMC, and Ammo®) were the only pyrethroids to show synergistic activity on FAW. In each case, synergism decreased with increased age of the insects. Chang and Jordan (1982) showed that permethrin penetrated into *Wiseana cervinata* larvae faster than cypermethrin. Casida (1970) pointed out that most well-known synergists, including PB,

TABLE 1. TOXICITY OF NINE SYNTHETIC PYRETHROIDS ALONE (A) AND WITH PIPERONYL BUTOXIDE (1:8) (B) TO EGGS (SEVEN DAYS POST-TREATMENT), THIRD, AND SIXTH INSTAR (24H POST-TREATMENT) OF *Spodoptera frugiperda*.

Compound	Eggs (LC_{50}[1])			3rd instar (LD_{50}[2])			6th instar (LD_{50}[2])		
	(A)	(B)	SR[3]	(A)	(B)	SR[3]	(A)	(B)	SR[3]
Pay-Off®	0.320	0.360	0.890 NS	0.0407	0.0153	2.6601 NS	0.306	0.524	0.584 NS
Mavrik®	1.164	0.866	1.344 NS	0.0487	0.0189	2.5757 NS	1.456	1.121	1.299 NS
permethrin (FMC)	1.378	2.198	0.627 NS	0.0041	0.0019	2.1579 NS	0.213	0.330	0.646 NS
permethrin (ICI)	1.572	0.813	1.934 NS	0.0067	0.0042	1.5952 NS	0.662	0.781	0.848 NS
cypermethrin (FMC)	1.557	0.441	3.531 *	0.0307	0.0100	3.0700 *	0.250	0.341	0.748 NS
cypermethrin (ICI)	2.006	0.317	6.328 *	0.1327	0.1155	1.1489 NS	0.684	0.431	1.587 NS
Pounce®	4.000	3.754	1.066 NS	0.0271	0.0093	2.9140 NS	3.471	4.246	0.817 NS
Ammo®	7.375	3.875	1.903 NS	0.1558	0.0171	9.1111 *	5.841	0.676	8.641 *
Pydrin®	12.230	15.405	0.794 NS	0.1277	0.1085	1.1770 NS	0.813	0.591	1.376 NS

[1]LC_{50} = Concentration to kill 50% of individuals tested (ppm).
[2]LD_{50} = Dosage to kill 50% of individuals tested (μg/insect).
[3]SR = Synergistic ratio = (A)/(B).
*Significantly greater than 1.0 at $p \leq 0.05$; NS, not significantly greater than 1.0.

are fat-soluble and therefore favor penetration through the insect cuticle. Pepper and Hastings (1943) and Gast (1961) found that, during larval development, the insect cuticle varied in its composition. For example, lipid content causes changes in insecticide susceptibility. Thus, it is possible that the small residual factor of synergism shown by cypermethrin may be explained by physical effects of the large dose of lipophilic synergist on penetration as well as the increased penetration of the pyrethroid itself. The decrease in insecticide susceptibility with increased larval age of FAW could also be due to an increase in insecticide metabolizing enzymes in older larvae (Yu 1983).

Yu (1982) indicated that an increase in detoxifying enzymes due to host plant induction results in a protective effect against various insecticides, including pyrethroids, in FAW. This is supported by Wood et al. (1981) who showed that FAW susceptibility to insecticides, including permethrin, varied with the host plant. In view of this, addition of a synergist to pyrethroids to increase their insecticidal potency and cost efficiency is tempting; however, concomitant alterations in mammalian toxicity may shift compounds otherwise considered safe into a hazardous category (Casida and Ruzo 1980).

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CAULOTOPS DISTANTI (MIRIDAE: HETEROPTERA), A POTENTIAL YUCCA PEST NEWLY DISCOVERED IN THE UNITED STATES

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ABSTRACT

The plant bug *Caulotops distanti* (Reuter) is reported for the first time in the United States based on specimens collected in two Florida nurseries damaging potted cuttings of *Yucca elephantipes* Regel (Agavaceae). Because some of the potted plant material infested with *C. distanti* has been sold, this potential *Yucca* pest is considered at least temporarily established in the United States. *Caulotops distanti* was imported from Costa Rica, probably as eggs inserted in the stems of its host. A diagnosis and key are provided to help separate *C. distanti* from other U. S. species of *Caulotops* and the morphologically similar *Halticotoma valida* Townsend.

RESUMEN

Se reporta por primera vez en los Estado Unidos a *Caulopos distanti* (Reuter), basado en muestras colectadas en dos viveros, dañando plantas de *Yucca elephantipes Regel* (Agavaceae) sembradas en jarrones. Puesto que algunas de estas plantas infestadas con *C. distanti* han sido vendidas, esta posible plaga de *Yucca* es por lo menos temporalmente considerada establecida en los Estados Unidos. *Caulotopos distanti* fue importada de Costa Rica, posiblemente como huevos insertados en los tallos del hospedero. Se provee un diagnóstico y una clava para ayudar a separar a *C. distanti* de otras especies de *Caulotops* de los Estados Unidos y del morfologicamente similar *Halticotoma valida* Townsend.

The plant bug *Caulotops distanti* (Reuter) is here reported for the first time in the United States based on specimens submitted to the Systematic Entomology Laboratory, IIBIII, Agricultural Research Service, USDA, Washington, D.C. In this paper I outline the steps leading to the discovery of this mirid, present comments on its economic potential, and provide a diagnosis and key to the U. S. species of *Caulotops*.

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ABSTRACT

The plant bug *Caulotops distanti* (Reuter) is reported for the first time in the United States based on specimens collected in two Florida nurseries damaging potted cuttings of *Yucca elephantipes* Regel (Agavaceae). Because some of the potted plant material infested with *C. distanti* has been sold, this potential *Yucca* pest is considered at least temporarily established in the United States. *Caulotops distanti* was imported from Costa Rica, probably as eggs inserted in the stems of its host. A diagnosis and key are provided to help separate *C. distanti* from other U. S. species of *Caulotops* and the morphologically similar *Halticotoma valida* Townsend.

RESUMEN

Se reporta por primera vez en los Estado Unidos a *Caulopos distanti* (Reuter), basado en muestras colectadas en dos viveros, dañando plantas de *Yucca elephantipes Regel* (Agavaceae) sembradas en jarrones. Puesto que algunas de estas plantas infestadas con *C. distanti* han sido vendidas, esta posible plaga de *Yucca* es por lo menos temporalmente considerada establecida en los Estados Unidos. *Caulotopos distanti* fue importada de Costa Rica, posiblemente como huevos insertados en los tallos del hospedero. Se provee un diagnóstico y una clava para ayudar a separar a *C. distanti* de otras especies de *Caulotops* de los Estados Unidos y del morfologicamente similar *Halticotoma valida* Townsend.

The plant bug *Caulotops distanti* (Reuter) is here reported for the first time in the United States based on specimens submitted to the Systematic Entomology Laboratory, IIBIII, Agricultural Research Service, USDA, Washington, D.C. In this paper I outline the steps leading to the discovery of this mirid, present comments on its economic potential, and provide a diagnosis and key to the U. S. species of *Caulotops*.

Recently, I received 5 females of an undetermined *Caulotops* (submitted by F. W. Mead, Fla. St. Colln. Arthropods, Gainesville) collected by Paul Gibson in a nursery at Apopka, Orange Co., Florida, 6-VII-1984, on *Yucca elephantipes* Regel (Agavaceae). A later collection (9-VIII-1984) by Mr. Gibson (Fla. Dept. Agric.) of 33 specimens containing males taken in the same nursery on potted *Yucca elephantipes* allowed me tentatively to identify the species as *Caulotops distanti* (Reuter). By comparing external morphology and male genitalia to paratypes of Carvalho's *C. rufoscutellatus* (a junior synonym of *C. distanti*) series, I have been able to confirm my earlier identification. Further, study of paratypes of the subspecies *C. distanti major* Carvalho, 1948, suggests that this Mexican form is only a color variant of the nominate subspecies *C. distanti distanti* (Reuter) and is here considered a synonym.

The original of the *C. distanti* population has been traced to at least two nurseries located in north central Florida. The plant material was imported from Costa Rica as unrooted tips planted three per pot. At the time of importation, the cuttings were inspected and considered pest free, indicating that the population of *C. distanti* probably arrived as eggs inserted in the stems of the *Y. elephantipes*. Of the 375 original pots, 250 were sold and distributed to buyers in Louisiana, Maryland, Massachusetts, Michigan, Missouri, North Carolina, Ohio, Quebec, and Virginia. The remaining 125 pots were rendered unsalable in 6 months by the *C. distanti* population and have been destroyed.

Because the feeding habits and damage inflicted are similar to that of *Halticotoma valida* Townsend (Wheeler, 1976), it is likely that yucca plantings supporting populations of *C. distanti* can be killed if this pest is not controlled. It is doubtful that *C. distanti* can survive in climates as far north as Maryland or Virginia (or the northern range of *H. valida*), but yucca plantings in the more southern states could be considered susceptible. Because of the damage produced on the nursery stock in Florida, this species should be considered a pest of ornamental *Yucca elephantipes*, and possibly other native and ornamental *Yucca* spp.

Taxonomic history.—*Caulotops distanti* was described in the genus *Euryciptia* from Venezuela (Reuter, 1905) and later transferred to Bergroth's genus *Caulotops* (Reuter, 1908). Carvalho (1948) described the species *Caulotops rufoscutellatus*, also from venezuela, and the subspecies *Caulotops rufoscutellatus major* from Yucatan, Mexico (the latter here considered only a color form of *C. distanti*). After studying type material, Carvalho (1954) synonymized his species *C. rufoscutellatus* with *C. distanti.* The adult male and male genitalia [as *C. rufoscutellatus*] have been illustrated (Carvalho, 1948).

Distribution.—In addition to the Venezuelan [type-locality of *C. rufoscutellatus*], Mexican [type—locality of *C. rufoscutellatus* major], and Florida specimens, I have examined a series of 17 adults and 7 nymphs in the USNM collection that were taken on *Yucca* sp. at Brownsville, Texas, 19 Oct. 1944, apparently intercepted on plants originating from the Neotropics. With these records, *C. distanti* is now known to occur in Costa Rica, Mexico, and Venezuela. Its establishment in the United States (possibly Florida, Louisiana, North Carolina, Virginia, and Texas) needs further confirmation.

Diagnosis of C. distanti.—Male: Length 3.40-3.62 mm, width 1.50-1.56 mm.

Head: Width 0.96-1.00 mm, width of vertex 0.62 mm. Rostrum: Length 1.26-1.30 mm, extending slightly beyond bases of metacoxae. Antenna: Segment I, length 0.44-0.46 mm; II, 0.60-066 mm; III, 0.56-0.62 mm; IV, 0.54-0.60 mm. Pronotum: Length 0.64-0.70 mm, basal width 1.22-1.26 mm.

Female: Length 3.67-4.08 mm, width 1.67 mm. Head: Width 1.04-1.06 mm, width of vertex 0.64-0.66 mm. Rostrum: 1.34-1.36 mm. Antenna: I, 0.46-0.48 mm; II, 0.62-0.68 mm; III, 0.64-0.66 mm; IV, 0.64-0.68 mm. Pronotum: Length 0.68-0.72 mm, basal width 1.32-1.38 mm.

General coloration of head, pronotum, scutellum, venter, and legs pale yellowish brown to orange; hemelytra fuscous to bluish black. Head: Color as above with epicranial suture stippled with red, frons with 7-8 transverse brownish marks on each side of meson, these more distinct on pale, yellowish-brown individuals, apex of tylus fuscous. Pronotum: Color as above with calli infuscated on pale individuals; scutellum uniformly yellow to orange. Hemelytra colored as above, usually with a pale yellow to orange wedge-shaped streak beginning narrowly at base or middle of corium and broadly expanding at cuneal fracture; membrane and veins fumate. Venter uniformly yellow to orange, abdomen sometimes slightly infuscated. Antenna: Segment I pale yellowish brown, apex and narrow sub-basal ring fuscous; segments II-IV fuscous. Legs: Yellowish to orange; bases of femora and apices of coxae paler on orange individuals.

Remarks.—The genus *Caulotops*, previously represented in the United States by *C. agavis* Reuter and *C. barberi* Knight (both known only from Arizona), is most similar to the genus *Halticotoma*. Knight (1968) provided a key to separate the two genera, using the form of the calli as the distinguishing character. As currently defined, species of *Halticotoma* have the calli relatively smooth and undifferentiated, the body broadly rounded, and the hosts are primarily species of *Yucca* (Agavaceae). Species of *Caulotops* have distinctly raised calli with a depression between them, the body is more slender and elongate, and the hosts generally are species of *Agave* (Agavaceae). Unfortunately, these morphological characters and host preferences intergrade when all species in both genera are compared. A thorough analysis of the two genera, with a comparison of genitalia, is needed to clarify their relationships. The following key will separate the U.S. species of *Caulotops*.

Key to the U. S. species of *Caulotops*

1. Body length 4.1 mm or less; first antennal segment pale with apex and sub-basal ring fuscous; central area of corium usually with yellow or orange wedge-shaped streak ..... *distanti* (Reuter)
   Body length 4.6 mm or greater; first antennal segment uniformly black; hemelytron uniformly bluish black 2
2. Antennal segment II longer than width of vertex and single eye combined; tubercle on left side of male genital segment thick and bluntly rounded apically ..... *agave* Reuter
   Antennal segment II shorter than width of vertex and single eye combined; tubercle on left side of male genital segment slender and acute apically ..... *barberi* Knight

In the eastern United States, *C. distanti* keys to *Halticotoma valida* in Blatchley (1926). *C. distanti* is easily separated from *H. valida* by the current generic definition of characters in having the body more slender and the calli raised and separated by a distinct mesal groove. *C. distanti* is

further separated from *H. valida* by the pale first antennal segment that has the apex and a sub-basal ring fuscous (first segment uniformly black on *valida*), the uniformly yellow or orange scutellum (scutellum mostly fuscous on *valida*), and the larger size (*valida* ranges from 2.8-3.5 mm, but most individuals are 3.0-3.3 mm).

ACKNOWLEDGMENTS

I thank F. W. Mead and P. Gibson for providing biological and regulatory information on this species.

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NOTES ON THE GENUS *EUPHYES*, WITH DESCRIPTION OF A NEW SUBSPECIES (LEPIDOPTERA: HESPERIIDAE)

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ABSTRACT

A new subspecies of *Euphyes pilatka* (W. H. Edwards) is described from the Florida Keys and compared with the nominate subspecies. The

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ABSTRACT

A new subspecies of *Euphyes pilatka* (W. H. Edwards) is described from the Florida Keys and compared with the nominate subspecies. The

subspecies of *Euphyes conspicua* (W. H. Edwards) are discussed, and the name *orono* (Scudder) is resurrected for the east coast subspecies.

RESUMEN

Una subespecies nueva de *Euphyes pilatka* (W. H. Edwards) es descrita de los Cayos de la Florida y comparada con la subespecies typica. Las subespecies de *Euphyes conspicua* (W. H. Edwards) son discutidas, y el nombre *orono* (Scudder) es restablecido para la subespecies de la costa este.

The genus *Euphyes* contains ten Nearctic species (L. Miller and F. M. Brown 1981: 45-46), most of which are restricted to moist to swampy environments. Because of this ecological restriction, a number of taxa are found only in small demes that are isolated from other such populations by more or less uncrossable barriers. Most of the species have been considered to be monomorphic throughout their ranges, but examination of long series of these butterflies from several localities suggests that this situation is by no means as simple as it seems. During the past 60 years a number of new *Euphyes*, both species and subspecies, have been described (Lindsey 1923, Bell 1941, Ehrlich and Gillham 1951, Freeman 1975, J. Brown and McGuire 1983). Thus, the recognition of other taxa should surprise no one.

The two species dealt with in this paper are both fairly common throughout their ranges, but seldom is material from disparate localities compared, most examinations being restricted to specimens from one or two populations; the differences between demes cannot be detected unless species are sampled from throughout their ranges.

Euphyes pilatka (W. H. Edwards), 1867

This name, originally spelled as above, was emended to *"palatka"* by Scudder (1872: 80), based on the change of spelling of the Florida town name from "Pilatka" to "Palatka". The emendation of the town's name was promulgated by the U. S. Post Office, because it was felt that the original spelling would cause confusion with the nearby town of Picolata (Morris 1974). The history of Scudder's unjustified emendation is further summarized in F. M. Brown and L. Miller (1980: 83, 86).

This species is not uncommon in Florida and extends northward and westward on the Coastal Plain to Virginia and Mississippi (MacNeill 1975: 448) wherever sawgrass, *Mariscus jamaicensis* Crantz (CYPERACEAE) is prevalent in swampy habitats. Individual demes vary, but in many only a few adults are present at any one time (populations on at least the southern periphery of the range may have fewer than a dozen specimens flying, though many additional members of the deme may be present as eggs, larvae or pupae).

Almost all of the definitive records are from the mainland U. S., with the exception of a single female recorded by Kimball (1965: 55-56) from Sugarloaf Key, Monroe Co., Florida, which Klots reportedly suspected of being representative of a new subspecies. Kimball, however, states that, "Symmes has a series from Big Pine Key which are all definitely typical. . ." Nevertheless, we decided to investigate the Lower Keys population and over a period of years have accumulated a significant number of specimens.

None of the Big Pine Key, Sugarloaf Key or Stock Island specimens that we have taken or seen is typical, and all represent a new taxon, herein described:

Euphyes pilatka klotsi L. Miller, Harvey and J. Miller, new subspecies

Male (Figures 1-2): Similar to ♂ of *E. p. pilatka* (Figures 5-6), but differing in the following respects: upper forewing slightly redder and with increased basal fuscous shading and with marginal fuscous border encroaching on median fulvous patch resulting in a less extensive fulvous area; subapical spots usually prominent (these are generally coalesced with and obliterated by the fulvous median area in nominate *E. pilatka*); hindwing above with greatly reduced fulvous median shading; hindwing beneath with ground color much darker fuscous than in nominate race.

Male genitalia (Figures 11-15) as illustrated. As with a number of hesperiine species, the valvae are asymmetrical in *E. pilatka* with a great deal of variation along the costal margin (Figures 11-18) which may be dentate or smooth. The cucullus in the new subspecies, *E. p. klotsi*, is more produced, whereas that of the nominate subspecies is rather blunt. The setal and associated scale tufts along the costa and sacculus are consistently more pronounced and thicker in the new subspecies, with the setal patch along the inner margin of the cucullus more extensive than in *E. p. pilatka*.

Length of forewing of Holotype: ♂ 19.6 mm.; those of the 43 ♂ paratypes range from 18.0 to 20.4 mm., averaging 19.29 mm.

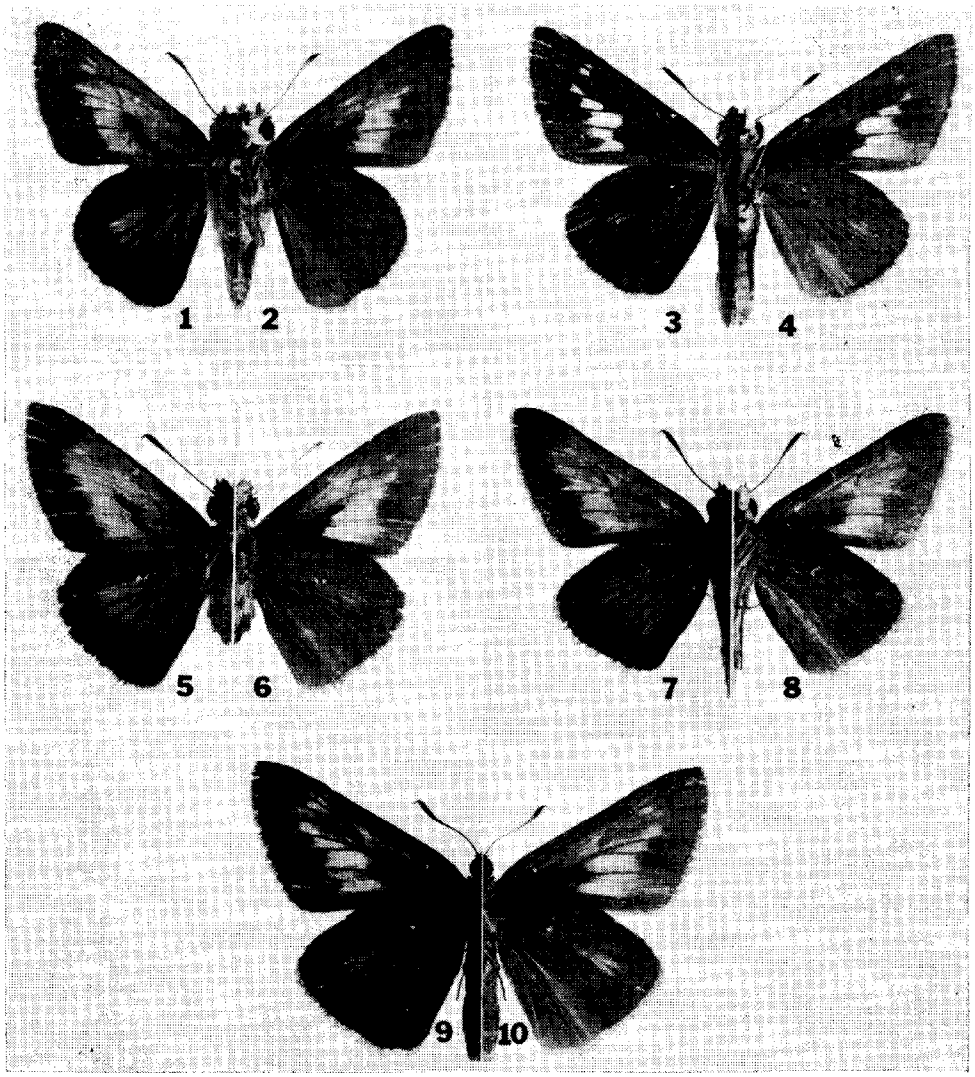
Female (Figures 3-4): Much darker above and below than ♀ of *p. pilatka* (Figures 7-10); no, or only a trace of, fulvous basal suffusion on upper forewing of the present subspecies (most specimens of nominate *E. pilatka* have strong fulvous suffusion nearly to the base of wing); subapical forewing spots (occasionally only one of these present) always separate from median fulvous spots from M_3-Cu_1 through Cu_2-2A (these spots usually coalesced by means of additional spots in M_1-M_2 and M_2-M_3 in *E. p. pilatka*); upper hindwing with central area reduced to at most a dash in Rs-M_2 (a broad diffuse fulvous area in nominate subspecies) and under hindwing very much darker than in nominate subspecies.

Female genitalia (Figure 19) as illustrated, with a somewhat less heavily sclerotized anterior part of the ductus bursae near where it joins the bursa copulatrix and slightly differently shaped lamella antevaginalis than nominate *E. pilatka* (Figure 20). The figures illustrate the two rather similar morphological types which may be observed in this species, but there as much variation in the degree of sclerotization of the ductus bursae at the juncture of the bursa copulatrix within populations as between demes. The ductus seminalis occurs on the lightly sclerotized portion of the bursa copulatrix and just beyond the juncture with the ductus bursae.

Lengths of forewings of the 18 ♀ paratypes range from 19.6 to 23.3 mm., averaging 21.28 mm.

Described from 62 specimens, 44 males and 18 females, from the Lower Florida Keys, Monroe Co., Florida.

HOLOTYPE ♂ :—FLORIDA: Monroe Co.: Sugarloaf Key, T66S, R27E, Sec. 23; 23.VI.1979 (D. J. Harvey); ♂ genitalia preparation M-3993-h (D. J. Harvey).



Figs. 1-10. *Euphyes pilatka* subspecies. 1-4: *E. p. klotsi*, new subspecies; Holotype ♂, upper (1) and under (2) surfaces (Allyn Museum photos 020180-16/17); FLORIDA: Monroe Co.: Sugarloaf Key; Paratype ♀, upper (3) and under (4) surfaces; FLORIDA: Monroe Co.: Big Pine Key (Allyn Museum photos 020180-18/19). 5-10: *E. p. pilatka* (W. H. Edwards); 5-6. ♂ upper (5) and under (6) surfaces; FLORIDA: Sarasota Co.: vic. Myakka Park (Allyn Museum photos 072580-11/12); 7-8, ♀ upper (7) and under (8) surfaces; FLORIDA: [Dade Co]: Royal Palm Park (Allyn Museum photos 072580-13/14); 9-10, ♀ upper (9) and under (10) surfaces; FLORIDA: "NE corner of Monroe Co." (Allyn Museum photos 072580-14/15).

PARATYPES:—all FLORIDA: Monroe Co.: 6 ♂ 1 ♀, same locality as Holotype, 22.VI.1979 (D. J. Harvey and J. Longino); 1 ♂ 2 ♀, same data and collector as Holotype; 1 ♂, Sugarloaf Key, 13.XI.1953 (C. P. Kimball); 4 ♂ 1 ♀, Sugarloaf Key, 11.IV.1975 (D. Oosting); 2 ♂, Sugarloaf Key, 28.IX.1980 (L. D. and J. Y. Miller); 1 ♂, Sugarloaf Key, *ex* pupa on *Mariscus*, emerged 9.X.1980 (D. J. Harvey); 1 ♂, Stock Island,

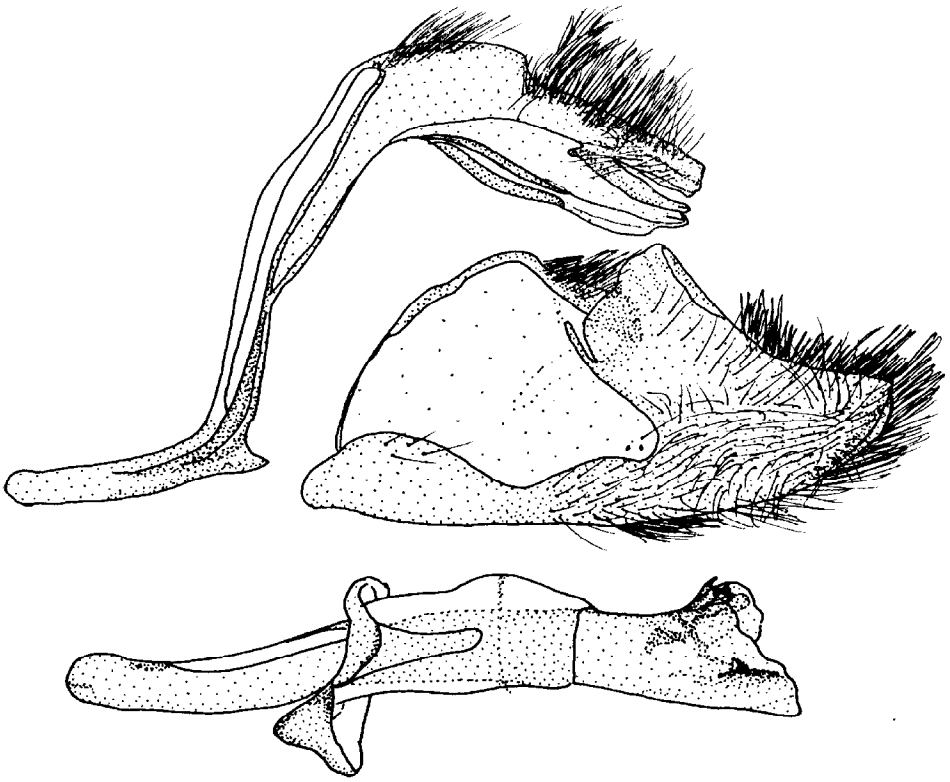


Fig. 11. ♂ genitalia of *Euphyes pilatka klotsi*, new subspecies (genitalia preparation M-3993-h [D. J. Harvey]). Note extensive associated setal and scale tufts.

26.XII.1970 (T. S. Dickel); 1 ♂, Big Pine Key, 1-5.IV.1951 (L. J. Sanford); 2 ♂, Big Pine Key, 1-5.I.1952 (L. J. Sanford); 5 ♂ 1 ♂, Big Pine Key, 1-5.II.1952 (L. J. Sanford); 3 ♂ 1 ♀, Big Pine Key, 3-7.II.1952 (L. J. Sanford); 1 ♀, Big Pine Key, 5-9.II.1952 (L. J. Sanford); 1 ♂, Big Pine Key, 24-29.III.1952 (L. J. Sanford); 1 ♂, "entrance to lane leading from paved road to Watson's Hammock," Big Pine Key, 17.II.1954 (L. Harris, Jr.); 1 ♂ 1 ♀, Big Pine Key, 30.XII.1977 (H. D. Baggett, Jr.); 1 ♂ 1 ♀, Big Pine Key, 4.IV.1978 (F. D. Fee); 1 ♀, Big Pine Key, 4.IX.1978 (T. S. Dickel); 1 ♂, Big Pine Key, 16.III.1979 (F. D. Fee); 1 ♂, Big Pine Key, 20.III.1979 (F. D. Fee); 1 ♀, Big Pine Key, 23.VI.1979 (D. J. Harvey); 2 ♀, Big Pine Key, 24.IX.1979 (L. D. and J. Y. Miller); 1 ♂ 1 ♀, Big Pine Key, 8.XII.1979 (D. S. Smith); 1 ♂ 1 ♀, Big Pine Key, 10.-III.1980 (F. D. Fee); 1 ♂ Big Pine Key, 29.VI.1980 (J. Weintraub); 4 ♂ 1 ♀, Big Pine Key, 28.IX.1980 (D. J. Harvey, L. D. and J. Y. Miller); 1 ♂ 1 ♀ Big Pine Key, 19.XII.1982 (J. Shuey).

Disposition of type-series: Holotype ♂, 3 ♂ and 2 ♀ Paratypes in Allyn Museum of Entomology, 15 ♂ and 3 ♀ Paratypes in American Museum of Natural History, 12 ♂ and 5 ♀ Paratypes in the collection of D. J. Harvey, 4 ♂ and 3 ♀ Paratypes in the collection of F. D. Fee, 3 ♂ and 1 ♀ Paratypes in the collection of D. F. Oosting, 1 ♂ and 1 ♀ Paratypes in the collection of T. S. Dickel, 1 ♂ and 1 ♀ Paratypes in the collection of D. S. Smith, 1 ♂ and 1 ♀ Paratypes in the collection

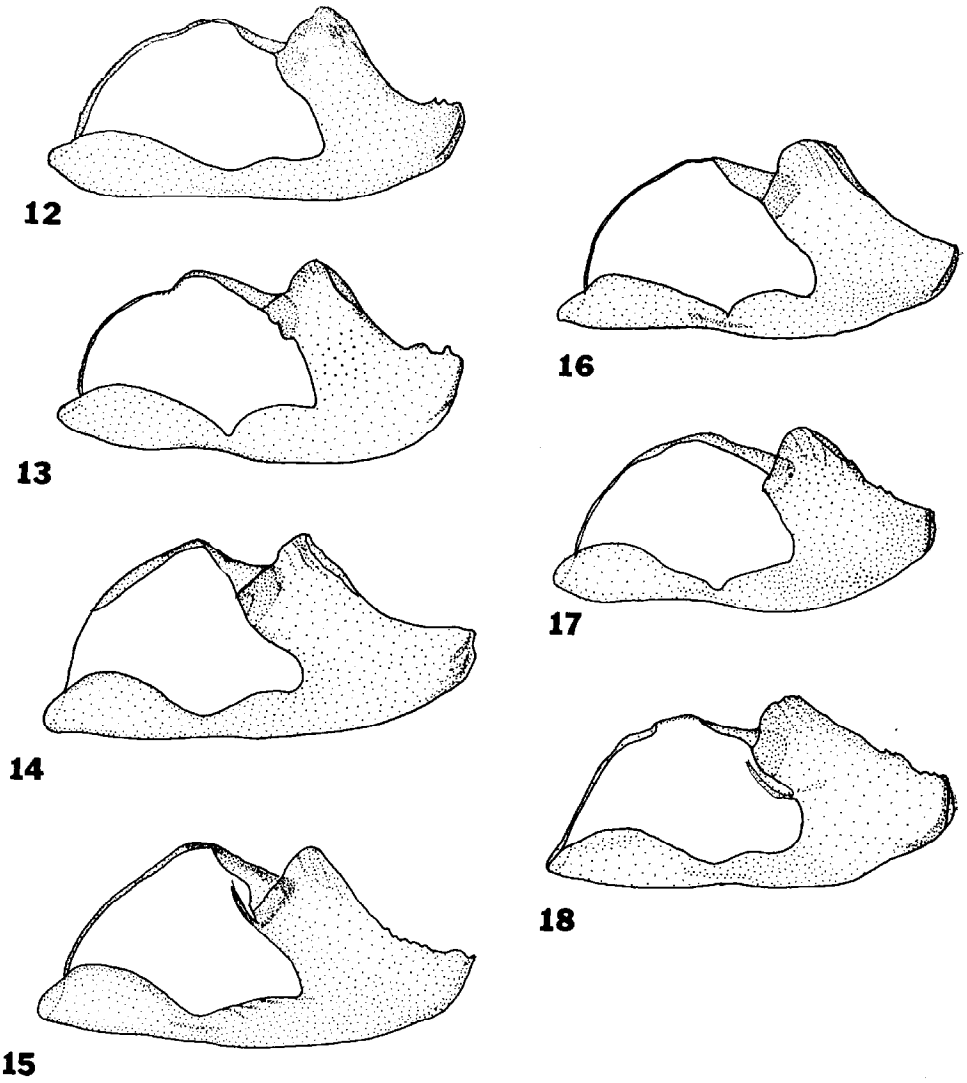


Fig. 12-18. Range of variation in valvae of *Euphyes pilatka*. 12-15, *E. p. klotsi*; 12, 13: FLORIDA: Monroe Co.: Sugarloaf Key [genitalic prep. M-6574, M-6881]; 14, 15; FLORIDA: Monroe Co.: Big Pine Key [genitalic prep. M-6586, M-3993-h]). 16-18, *E. p. pilatka*, all from FLORIDA: Sarasota (16, prep. M-3994-h), Monroe Co., Everglades National Park (17, prep. M-6578), and Franklin Co., Appalachicola (18, prep. M-6584).

of H. D. Baggett, Jr., 1 ♂ Paratype in the collection of C. P. Kimball, 1 ♂ Paratype in the collection of J. Weintraub and 1 ♂ and 1 ♀ Paratypes in the collection of J. Shuey.

Etymology: This subspecies is named in honor of Dr. A. B. Klots who first indicated its possible subspecific distinctiveness.

We have not seen any specimens of *E. pilatka* from the Upper or Middle Florida Keys, despite the fact that many of the islands such as Key Largo and Lower Matecumbe Key have been rather well collected. Such negative evidence does not *prove* that *E. pilatka* is absent from these Keys and that the apparent disjunction of the range is real, but it does strongly

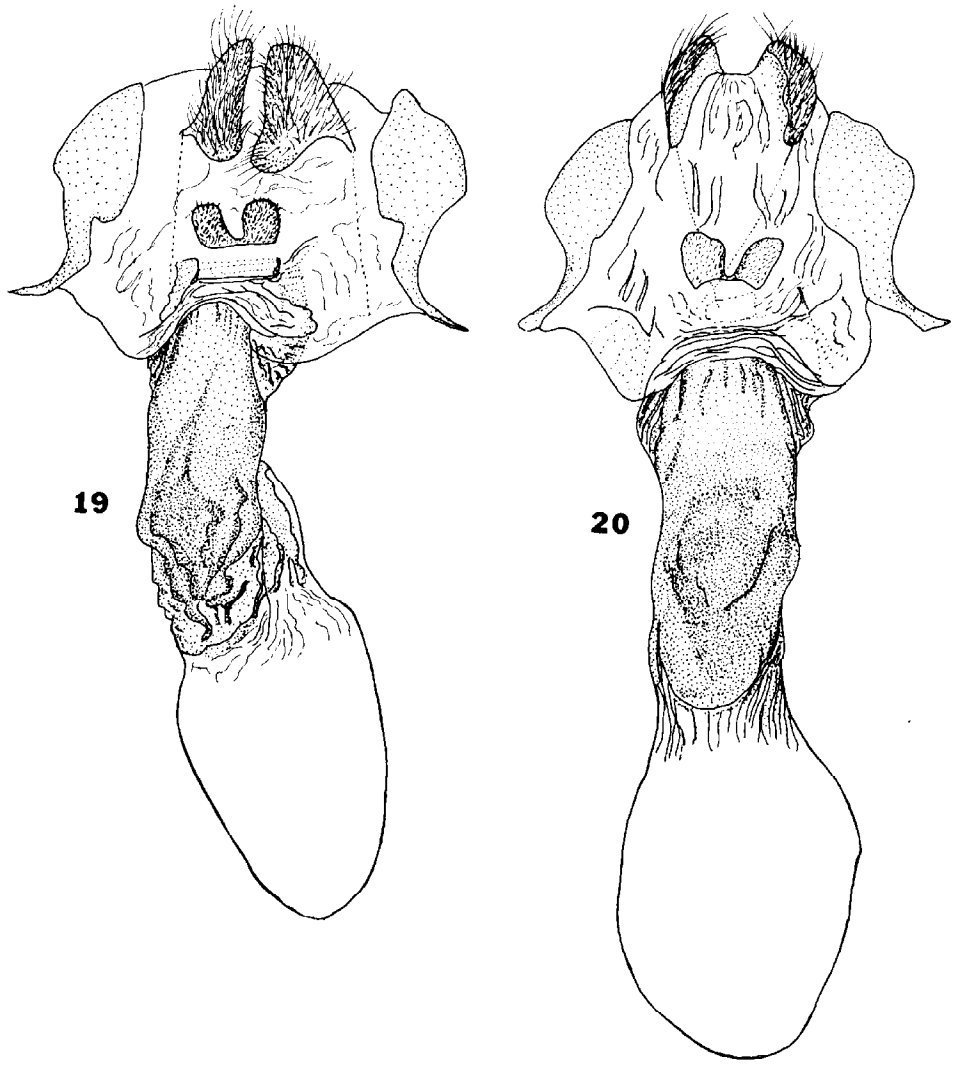


Fig. 19-20. ♀ genitalia of *E. pilatka*. Note the more heavily sclerotized and contorted base of the ductus bursae. 19, *E. p. klotsi*, new subspecies, Paratype (genitalia prep. M-6575); FLORIDA: Monroe Co.: Sugarloaf Key; 20, *E. p. pilatka* (genitalia prep. M-6579); FLORIDA: [Dade Co.]: Everglades National Park.

suggest that this is so. The nominate subspecies is common on the mainland of extreme southern Florida, and it seems likely that if *E. pilatka* occurred in the Upper Keys, it would have been discovered by now. The reasons for this apparent disjunction of the range of *pilatka* are obscure (there seems to be a similar disjunction of the range of *Hesperia meskei* (W. H. Edwards), according to W. W. McQuire, *in litt.*).

Specimens which we collected of *E. pilatka klotsi* were restricted usually to small patches of sawgrass that were in low places in the pine woods that cover much of Big Pine and Sugarloaf Keys. The adults seldom strayed far from the sawgrass areas, and all of our specimens were taken there. A search for immature stages was undertaken, and immediately we

found bundles of sawgrass blades stitched together by larvae. Few living larvae or pupae were found (although a number of empty pupal shells were found); one pupa hatched into *E. p. klotsi* in Sarasota, thus confirming the identification.

Additional collecting certainly needs to be done in northern Monroe County to ascertain whether or not populations connecting the present subspecies with *E. p. pilatka* exist. These intervening areas have been collected thoroughly in the past, but perhaps the sawgrass patches have been overlooked. We do know that such patches are not common from Big Pine Key to the mainland, and those that we sampled did *not* have *E. pilatka* populations.

Females are readily distinguished from mainland *E. pilatka* by the reduced maculation on both wings. Statistical analysis was done on the percentage of forewing vein Cu_2 that was covered by fulvous scales. *E. p. klotsi* (10 specimens) averaged 0.3591 ± 0.0095 fulvous, whereas *E. p. pilatka* (25 specimens) showed a value of 0.5092 ± 0.1018 fulvous; the differences between the means of the populations was not significant at the 95% level because of some rather dark examples of the mainland subspecies. These differed from Keys specimens in other respects (more subapical spots which were frequently coalesced with the median fulvous patch and greater basal fulvous suffusion). Similar characteristics separate males, through the differences are somewhat subtler, involving broader dark margins of the forewings above, reduced fulvous on the upper hindwing and the fulvous of the upper surface being ruddier. The only characteristic of these that is readily quantifiable involves the percentage of fulvous and fuscous scaling ("a" and "b-a" in Figure 21) along forewing vein 2A, and the results of statistical analyses for both *E. p. pilatka* and *E. p. klotsi* were significant. Big Pine Key male specimens (25) averaged 0.3149 ± 0.0046 fuscous along vein 2A, whereas mainland Florida male specimens (41) gave a value of 0.2771 ± 0.0043. These figures suggest that the two populations are significantly different in this character.

The statistical analysis of male specimens was clouded somewhat by two paratypes of *E. p. klotsi* collected by F. D. Fee on Big Pine Key which more closely resembled nominate *pilatka* than did other examples of the new subspecies. Genitalic examination of one of these specimens showed it to be similar to those previously dissected from the area, although there were some inconsistencies. These specimens were, however, included in the type-series of *E. p. klotsi.*

Euphyes conspicua (W. H. Edwards), 1863

L. Miller and Brown (1981: 45) summarize the synonymy of this species as of 1979-1980: two subspecies are recognized, *E. c. conspicua* and *E. c. buchholzi* (Ehrlich and Gillham), 1951. Examination of many more specimens, especially those in the Allyn Museum of Entomology from the collection of F. H. and P. W. Chermock, suggests that the situation may be more complicated than we first surmised.

Ehrlich and Gillham (1951: 188-189) characterize *E. c. buchholzi* as being larger and more robust than nominate *E. conspicua* with a "tendency towards obsolescence of the light markings on the underside of the primaries." They further state, "This character is found only occasionally in eastern

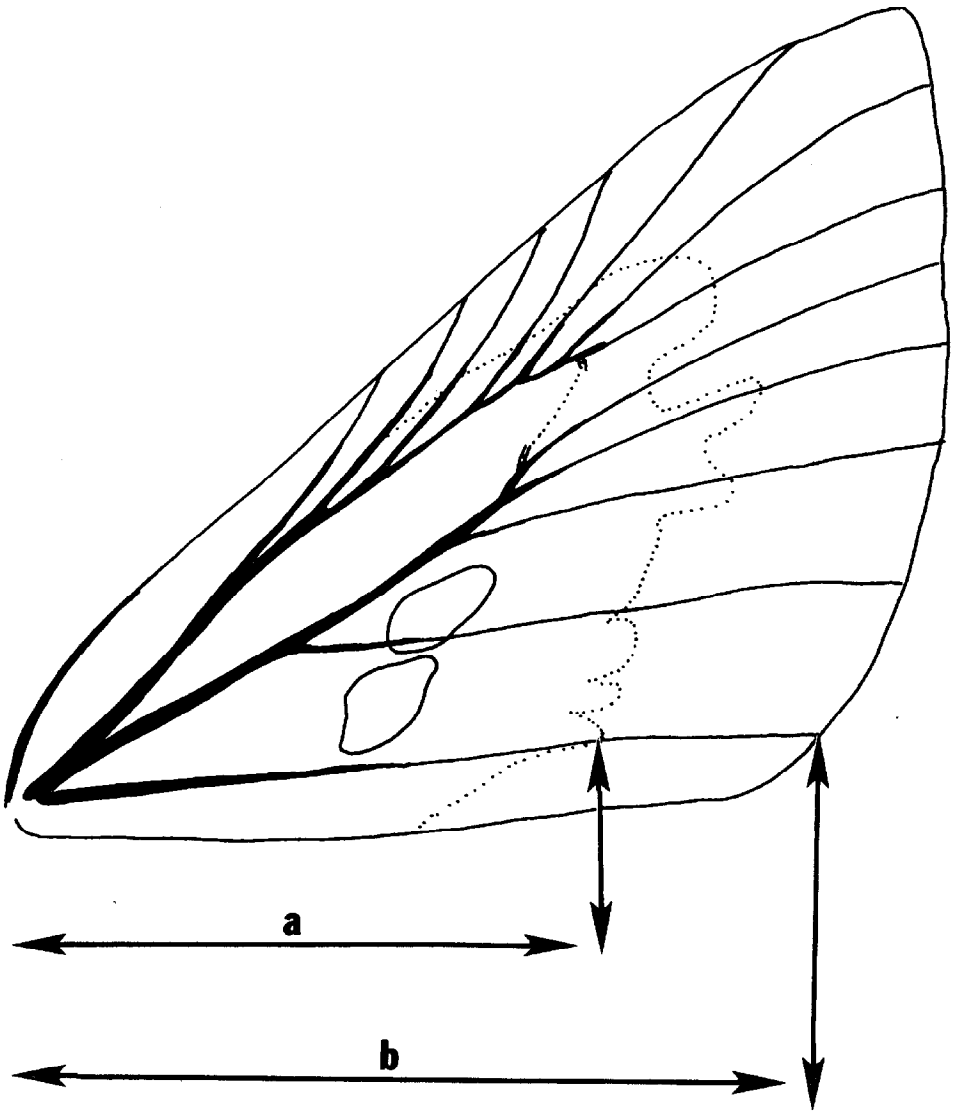


Fig. 21. Pattern of forewing of *E. pilatka* ♂ showing distal fuscous area and basal fulvous one. "a" is measured fulvous distance along vein 2A, "b" is total length of 2A: fuscous is denoted as "b-a".

specimens," and claim that "near topotypical *conspicua*" are identical with eastern material in these characteristics.

Material from New England, New Jersey, Pennsylvania and especially eastern Maryland is considerably darker (and usually smaller) than are topotypical specimens from near Lansing, Michigan. These eastern specimens have slightly to much reduced, but generally very prominent underforewing maculation. The males (except from Maryland, where they are distinctly ochreous) are often slightly ruddier above than are those of typical *E. conspicua*, and females have the pale markings of all wings reduced in size, but more clearly delimited, than do topotypical specimens. The late F. H. Chermock and his now-deceased son, Paul, noticed these differences and accumulated a large series of specimens from the vicinity of

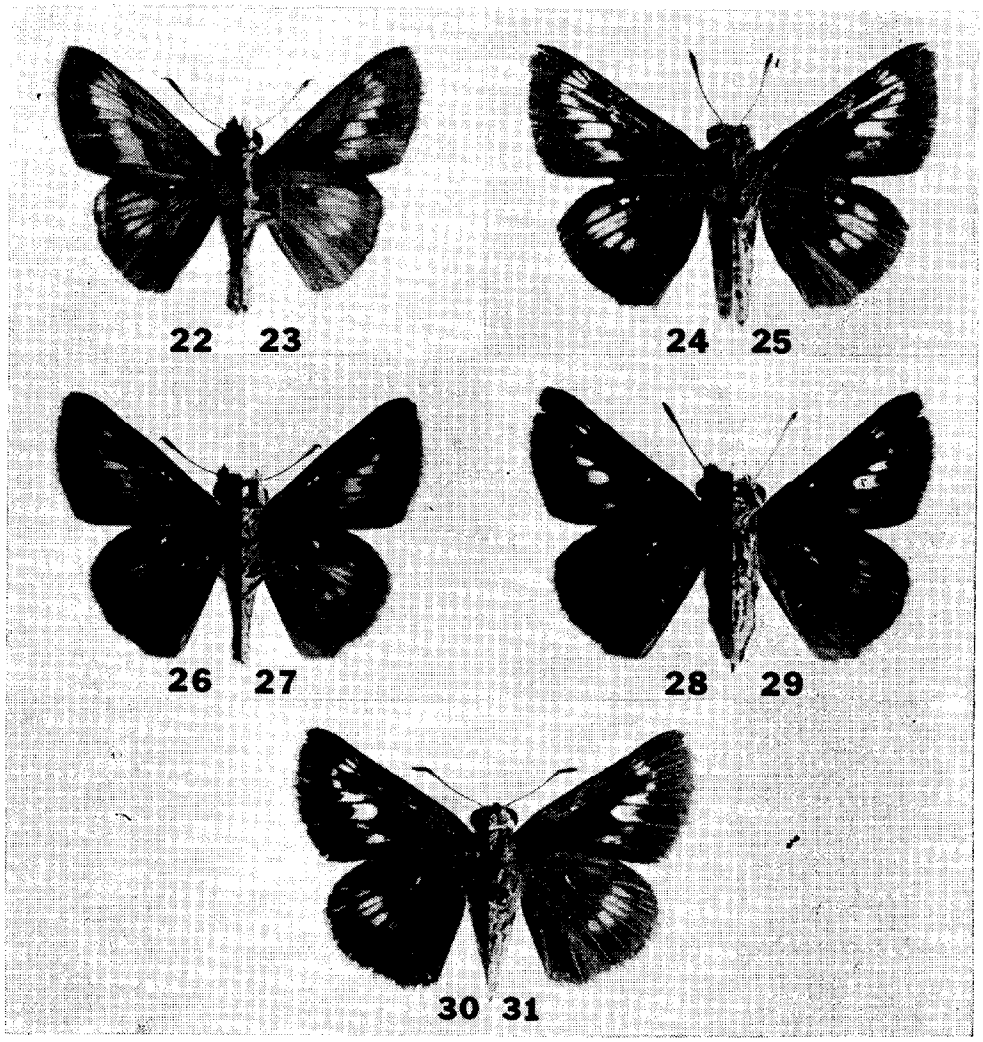


Fig. 22-31. *Euphyes conspicua* subspecies. 22-25: *E. c. conspicua* (W. H. Edwards); 22-23, ♂ upper (22) and under (23) surfaces; MICHIGAN: Ingham Co.: Dansville Game Area (Allyn Museum photos 072580-17/18); 24-25, ♀ upper (24) and under (25) surfaces; same locality (Allyn Museum photos 072580-1A/2A). 26-31: *E. c. orono* (Scudder); 26-27, ♂ upper (26) and under (27) surfaces; MARYLAND: Baltimore Co.: Stevenson (Allyn Museum photos 072580-9/10); 28-29, ♀ (dark morph) upper (28) and under (29) surfaces; same locality (Allyn Museum photos $72580-5/6); 30-31, ♀ (light morph) upper (30) and under (31) surfaces; same locality (Allyn Museum photos 072580-7/8).

Baltimore, Maryland (chiefly at Stevenson, Baltimore County), which they intended to use as the basis for the description of a new subspecies of *E. conspicua*. Paratypes of this putative taxon may have been distributed, but the specimens are within the range of variation of eastern *E. conspicua*, though they do average a bit darker with pale markings tending to be more ochraceous than specimens from Pennsylvania through New England. Specimens of this population are shown in Figures 26-31. If there was no available name for this eastern taxon, the proposed name

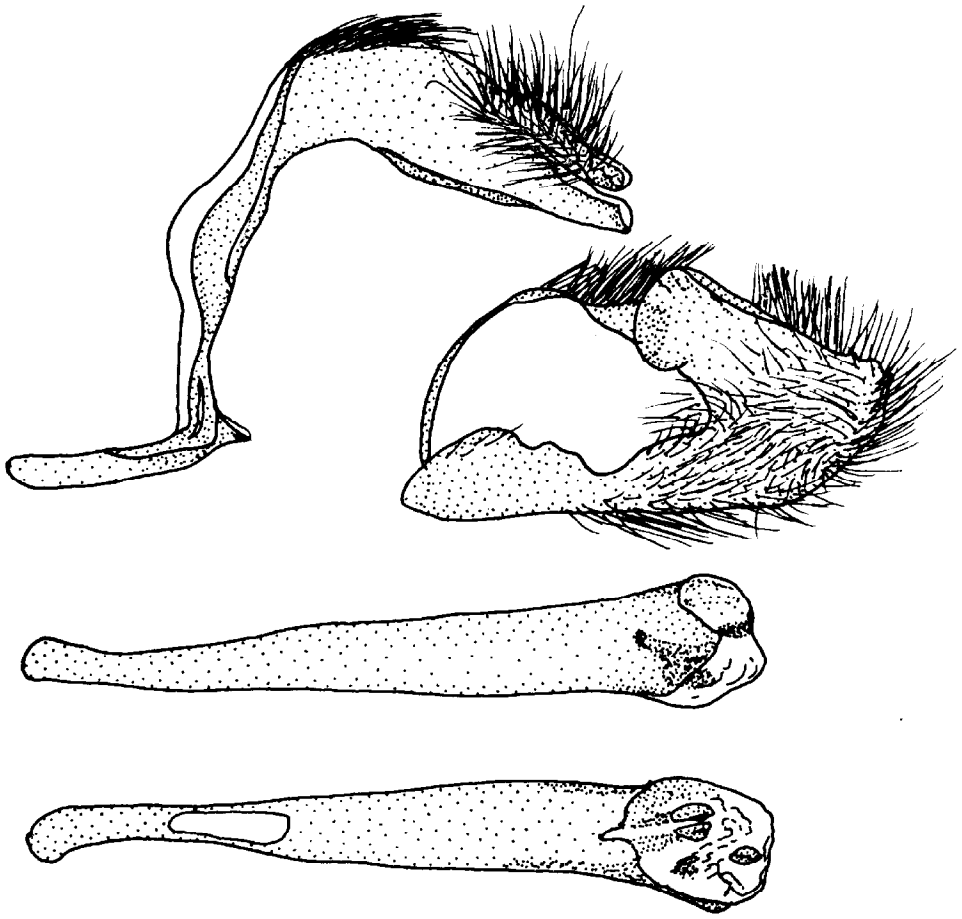


Fig. 32. ♂ genitalia of *Euphyes c. conspicua* (W. H. Edwards); MICHIGAN: Ingham Co., Dansville Game Area (genitalia prep. M-6659). Penis is drawn in dorsal view at bottom of figure as well as in lateral view just above it.

for the eastern specimens would have been in order, but Scudder (1872: 79) proposed the name *Hedone orono* for eastern *E. conspicua*. The type-locality for *E. orono* was given simply as "northern states", and it is unclear whether or not the specimens came from near the presentday town of Orono, Maine, or if Scudder simply used another of the Indian names he was so fond of employing, especially for hesperiids. The specimens from the eastern seaboard are sufficiently different, including those from Maryland, as explained above, from topotypical *E. conspicua* from the Great Lakes area (which are figured in Figures 22-25) to warrant the retention of the name *E. c. orono* for these populations. There seems to be a slight disjunction in the range of *E. conspicua* through western Pennsylvania and New York, mapped by Shapiro (1971: 134; fig. 5), which is a larger "gap" than that between populations of *E. c. conspicua* and *E. c. buchholzi*. The facies of specimens reflects the greater differences between the eastern seaboard and other populations as well.

Nevertheless, Ehrlich and Gillham (1951) described *E. c. buchholzi* strictly from eastern Nebraskan specimens with the comment (1951: 189)

that "Wisconsin and Iowa specimens are intermediate between *conspicua* and *buchholzi*, and should probably be designated as belonging to *Atrytone conspicua* Cl. *conspicua-buchholzi*." Most of the material that we have critically examined that might apply to this taxon has been from Iowa and Wisconsin in this complex, and these specimens seem to conform more to the concept of *E. c. buchholzi* than to that of *conspicua*. Until we see considerably more material referring to *E. c. buchholzi*, we must refrain from either synonymizing that name or confirming its identity. The male genitalia (Figure 32) do not differ significantly between populations. Positions of cornuti on the aedeagus are consistent.

Tentatively, we are accepting the distinctness of *E. c. buchholzi* and the necessity of dividing the eastern population from the Great Lakes one. This action leaves the following arrangement (numbers and letters refer to the running checklist in L. Miller and Brown, 1981):

213. conspicua (W. H. Edwards), 1863
  a. c. orono (Scudder), 1872
  b. c. conspicua (W. H. Edwards), 1863
    = *pontiac* (W. H. Edwards), 1863
  c. c. buchholzi (Ehrlich and Gillham), 1951

Acknowledgments

The following individuals and institutions loaned specimens that made this study possible: Dr. J. M. Burns (National Museum of Natural History), Dr. F. H. Rindge (American Museum of Natural History), Dr. Chen W. Young (Carnegie Museum of Natural History), F. D. Fee (State College, Pennsylvania), D. P. Oosting (Jenison, Michigan), Dr. D. Spencer-Smith (Oxford, England), J. Weintraub (Cambridge, Massachusetts), J. Shuey (Columbus, Ohio), H. D. Baggett, Jr. (Tampa, Florida) and T. S. Dickel (Homestead, Florida). Dr. J. Longino, formerly of Sarasota, Florida, helped collect some examples of *E. p. klotsi* during 1979. The late Dr. A. C. Allyn (Allyn Museum of Entomology) helped prepare the figures, and S. R. Steinhauser and Dr. W. Jenkins of the same institution read and commented on the manuscript. The comments of the anonymous reviewers were valuable and helpful.

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THREE NEW SPECIES OF *HETEROMURUS* (*ALLOSCOPUS*) AND DESCRIPTIVE NOTES FOR SPECIES OF THE SUBGENUS (COLLEMBOLA: ENTOMOBRYIDAE)

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ABSTRACT

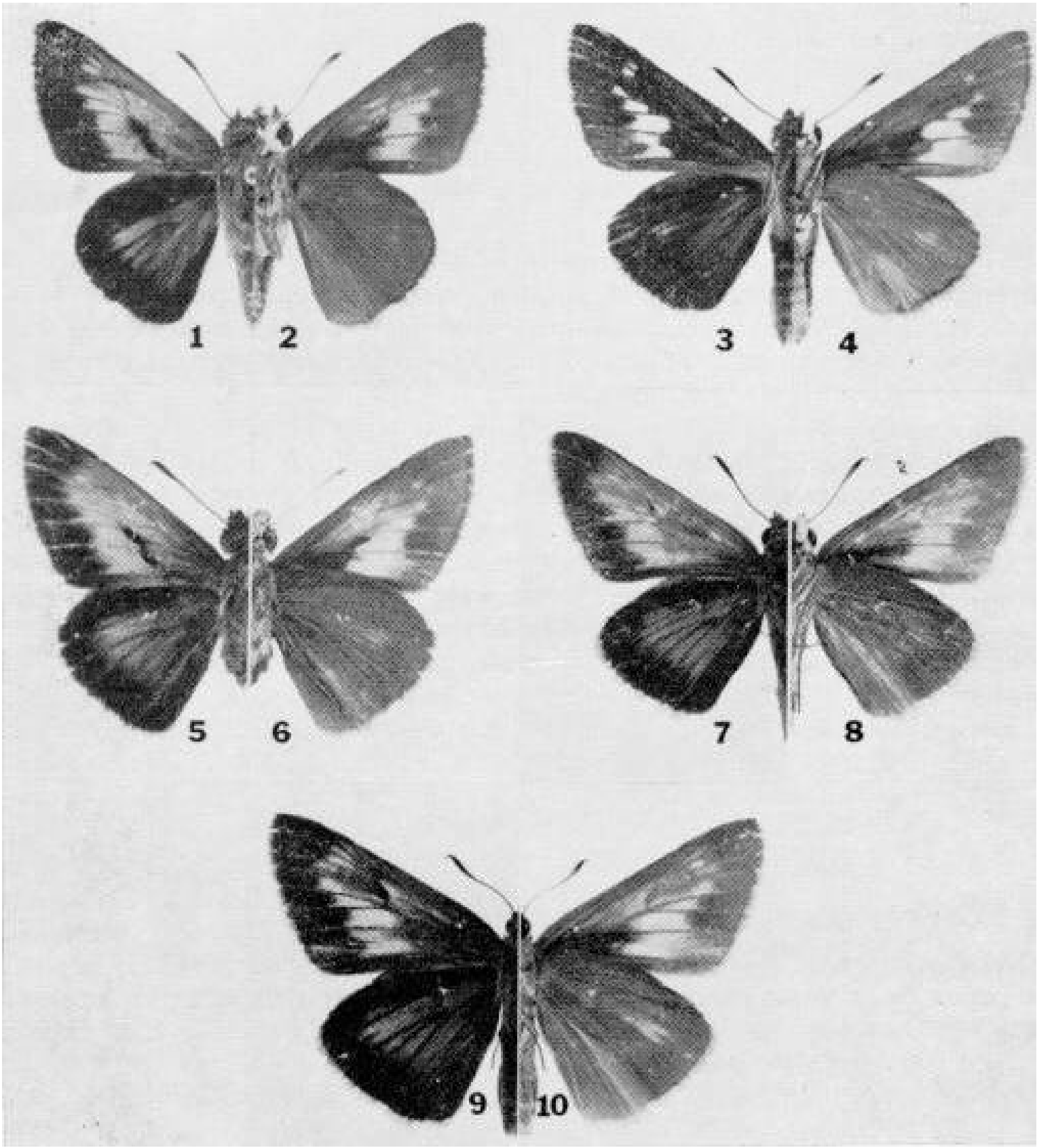
Three new species of *Heteromurus* (*Alloscopus*) are described: *H.* (*A.*) *thailandensis* from Thailand, *H.* (*A.*) *yosiius* from Indonesia, and *H.* (*A.*) *deharvengi* from Papua New Guinea. Details are added to the descriptions of *Heteromurus* (*Alloscopus*) *multispinatus* Mari Mutt, *H.* (*A.*) *tetracanthus* Börner and *H.* (*A.*) *tenuicornis* Börner based on specimens from Papua New Guinea and the Philippines. A key to the species of the subgenus is included.

RESUMEN

Se describen tres especies nuevas de *Heteromurus* (*Alloscopus*): *H.* (*A.*) *thailandensis* de Tailandia, *H.* (*A.*) *yosiius* de Indonesia y *H.* (*A.*) *deharvengi* de Papua Nueva Guinea. Se amplian las descripciones de *Heteromurus* (*Alloscopus*) *multispinatus* Mari Mutt, *H.* (*A.*) *tetracanthus* Börner y *H.* (*A.*) *tenuicornis* Börner en base a ejemplares de Papua Nueva Guinea y las Islas Filipinas. Se incluye una clave para las especies del subgénero.

During a recent visit to the laboratory of Dr. Louis Deharveng, Université Paul Sabatier, Toulouse, France, I gathered a large number of *Heteromurus* (*Alloscopus*) collected by Dr. Deharveng and his colleagues during expeditions to Thailand, the Philippines, Indonesia, and Papua New Guinea. The material includes three new species described below and specimens of the other three species described previously in *Alloscopus*.

The number given in parentheses after the collection data of each species corresponds to a locality number assigned by Dr. Deharveng. The holotype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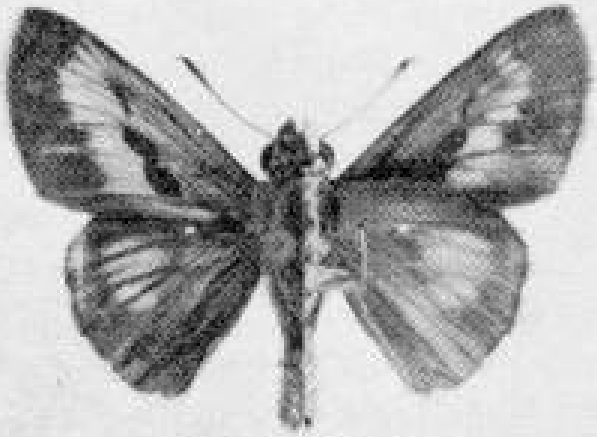

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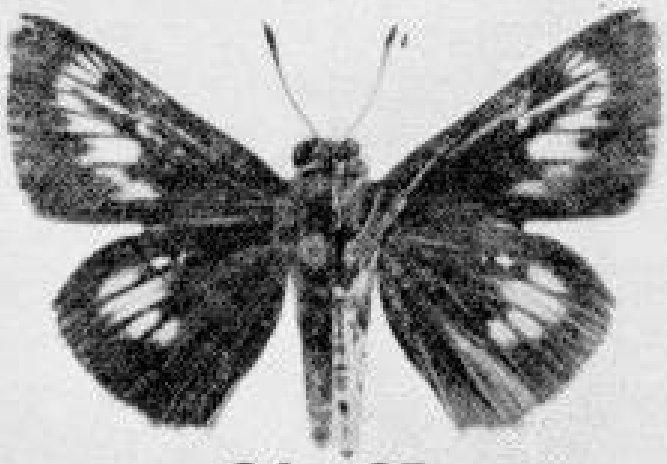

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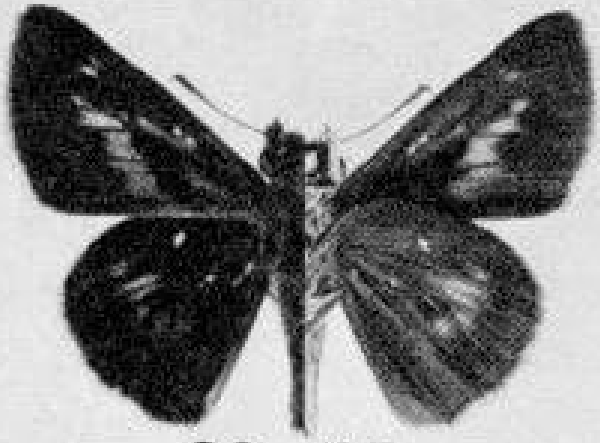

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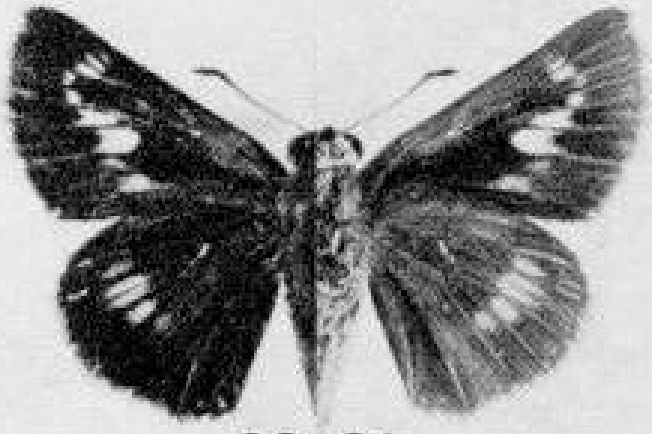

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ABSTRACT

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RESUMEN

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The number given in parentheses after the collection data of each species corresponds to a locality number assigned by Dr. Deharveng. The holotype

of *Heteromurus* (*Alloscopus*) *deharvengi*, n. sp., will be deposited in the Australian National Insect Collection, Canberra. Specimens of *H.* (*A.*) *multispinatus*, n. sp., listed without a locality number are on loan from the Bishop Museum, Hawaii, and will be returned to that institution. All the other specimens remain in my collection.

Morphological abbreviations used in this paper are as follows: Ant. 2, Th. 2, Abd. 2, etc. = 2nd antennal segment, 2nd thoracic segment, 2nd abdominal segment, etc.

The characters listed in the following paragraph are shared by all the species of the subgenus and will be deleted from the descriptions.

Heteromurus (*Alloscopus*)

DIAGNOSIS. Antennae 5-segmented. Pigment absent or restricted to a small eyepatch. Head with 13 S macrochaetae, a bothriotrix, and no macrochaetae posterior to macrochaeta Po. Inner pair of labral papillae large, conelike. Setae of maxillary palp similar in length and shape. Behind postlabial quadrangle (PLQ), near posterior margin of head, 2 + 2 ciliated setae (Fig. 26). Macrochaetotaxy of Abd. 1 to Abd. 4 as in Fig. 13. Abd. 4 dorsally about 1.5x length of Abd. 3. Unguiculus with large outer tooth. One smooth seta opposite tenent hair of metathoracic legs. Anterior margin of collophore without scales, corpus of tenaculum with a median seta. Dental spines present, mucronal spine absent.

Heteromurus (*Alloscopus*) *thailandensis* Mari Mutt, new species

Length to 1.7 mm. Head with small dark-red eyepatch but no eyes visible in cleared specimens. Apex of Ant. 5 with slender pin seta (Fig. 6). Arrangement of A and M macrochaetae as in Fig. 1; M3 present, $\bar{x}$ M1-A3/A3-A0 = 1.5 (1.2 — 2.0, n = 13). Length of postantennal organ about 2.4x socket diameter of macrochaeta An2 (Fig. 4, 5). Outer labral papillae rounded, with lateral conelike projections (Fig. 7, 8). Posterior portion of labium internal to seta e with 1 ciliated seta, 1 smooth seta and 1-2 scales; setae e, 1_1 and 1_2 smooth. Differentiated seta of outer labial papilla mounted on a small protuberance (Fig. 10), its apex close to or slightly surpassing apex of its papilla. Setae of PLQ smooth. Trochanteral organ with about 15 setae. Tibiotarsi without smooth setae. Inner margin of unguis with 1-2 unpaired teeth (Fig. 9), tenent hair accidentally missing in all specimens. Macrochaetotaxy of Th. 2 and Th. 3 as in Fig. 2, 3. Lateral anal valves without smooth setae. Dorsum of manubrium with 2 parallel rows of 4 + 4 smooth setae. Dens with 3-6 spines.

DIAGNOSIS: This species can be distinguished from all other members of the subgenus by the shape of the outer labral papillae (cf. Fig. 7, 8, 27; Mari Mutt 1978: 246, Fig. 16; Mari Mutt 1982: 90, Fig. 25).

HOLOTYPE: Thailand: Chiang Dao, base of platcau just north of the cave, route Luang Por Sim, 17-XII-1980, on bark, L. Deharveng and A. Gouze (16).

PARATYPES: Same data as holotype, on bark, soil, roots and leaf litter, 40 in alcohol and 12 on slides (2, 9, 11, 15, 16).

Heteromurus (*Alloscopus*) *yosiius* Mari Mutt, new species

Length to 1.8 mm. Eyes 1 + 1 surrounded by dark-red pigment. Apex

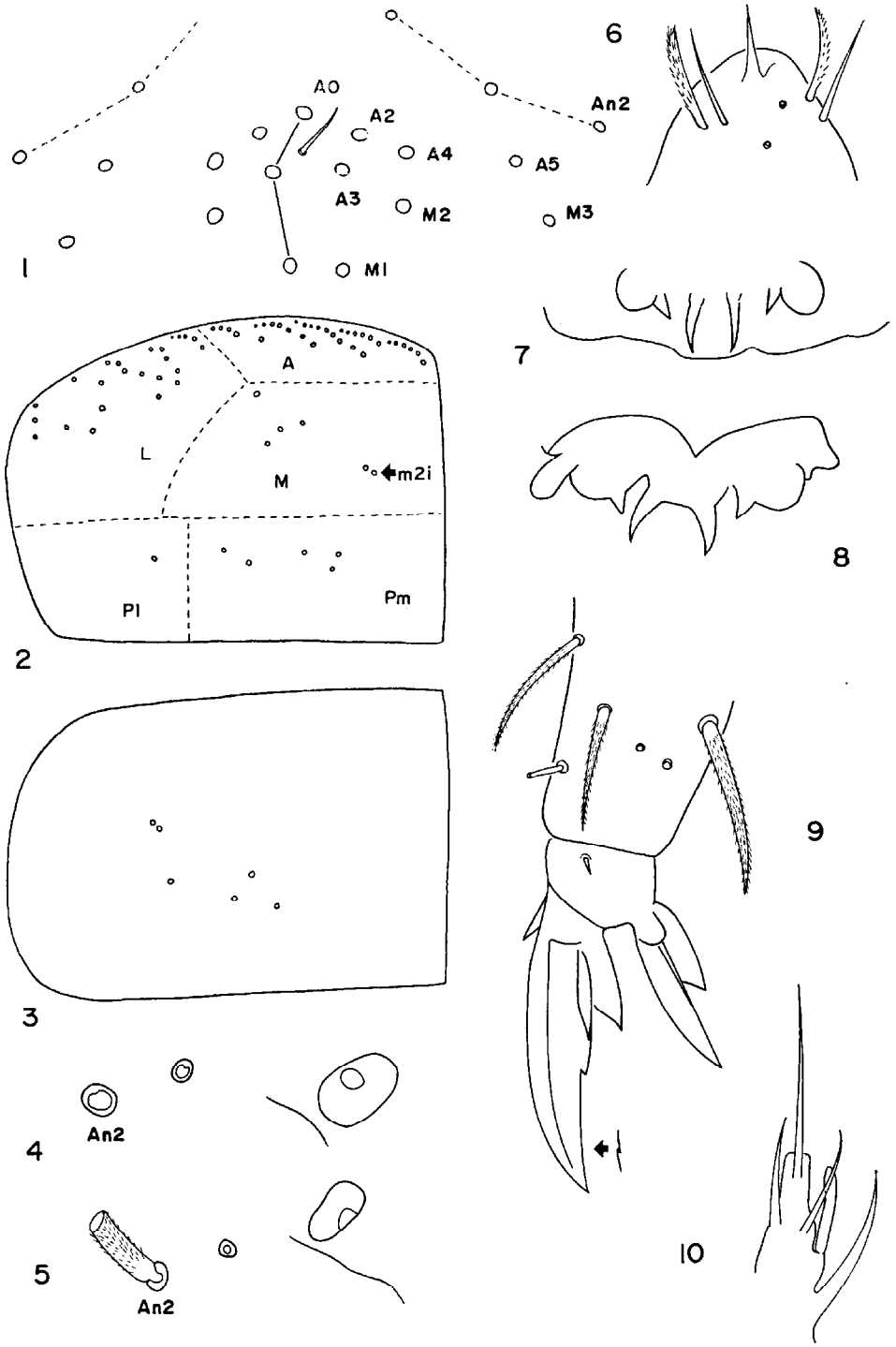

Fig. 1-10. *Heteromurus* (*Alloscopus*) *thailandensis*, n. sp. 1. Macrochaetotaxy of anterior portion of head; A = anterior, M = median, An = antennal. 2. Macrochaetotaxy of Th. 2; A = anterior, L = lateral, M = median, Pm = posteromedian, Pl = posterolateral. 3. Macrochaetotaxy of Th. 3. 4-5. Postantennal organ and 2 adjacent An macrochaetae. 6. Apex of Ant. 5. 7-8. Labral papillae. 9. Claws, arrow indicates position of optional unpaired tooth. 10. Outer labial papilla.

of Ant. 5 without pin seta but with 2 long, apically hooked setae. Arrangement of A and M head macrochaetae as in Fig. 11, M3 absent. $\bar{x}$ M1-A3/A3-A0 = 2.4 (n = 2: 1.9, 3.0). Length of postantennal organ about 2.8x socket diameter of macrochaeta An2 (Fig. 15, 16). Outer labral papillae conelike, as in *H.* (*A.*) *multispinatus* Mari Mutt (Fig. 27). Posterior portion of labium internal to seta e with 1 ciliated seta, 1 smooth seta and 2-4 scales; setae e and 1_2 smooth, L_1 ciliated. Differentiated seta of outer labial papilla mounted on a large protuberance (Fig. 12), its apex some distance behind apex of its papilla or reaching apex. Setae of PLQ smooth. Trochanteral organ with about 25 setae. Tibiotarsi without smooth setae. Inner margin of unguis (Fig. 14) without unpaired teeth, tenent hair lanceolate. Body macrochaetotaxy as in Fig. 13. Lateral anal valves with 0-1 smooth seta. Male genital plate with about 26 smooth setae arranged in 2 poorly defined concentric rows. Dorsum of manubrium with 2 parallel rows of 4 + 4 (5 + 5?) smooth setae. Dens with 6-10 spines.

DIAGNOSIS: The only other member of the subgenus with 4 macrochaetae on the Pm region of Th. 2 is *H.* (*A.*) *tetracanthus* Börner. The key to the species details the differences between these taxa.

HOLOTYPE: Indonesia: Bogor, Java, 1200m, X-1983, native collector (21).

PARATYPES: Same data as the holotype, 1 in alcohol and 1 on slide.

ETYMOLOGY: The species is named after Dr. Ryozo Yosii in recognition of his numerous contributions to the taxonomy of Oriental Collembola.

Heteromurus (*Alloscopus*) *deharvengi* Mari Mutt, new species

Length to 1.4 mm. Without eyes and pigment. Apex of Ant. 5 without hooked seta but with pin seta as in *H.* (*A.*) *thailandensis* and a short apically rounded sensilla. Arrangement of A and M head macrochaetae as in Fig. 19; M3 present, $\bar{x}$ M1-A3/A3-A0 = 1.3 (n = 3: 1.0, 1.2, 1.8). Postantennal organ small, irregular, seen only on 1 side of 1 specimen. Outer labral papillae as in *H.* (*A.*) *multispinatus* but apex sharply pointed. Posterior portion of labium internal to seta e with 1 ciliated seta, 1 smooth seta and 2 scales; setae e and 1_2 smooth, L_1 smooth or ciliated. Differentiated seta of outer labial papilla as in Fig. 21. Setae of PLQ smooth. Trochanteral organ with about 17 setae. Tibiotarsi with 2 rows of smooth setae along inner margin of segment and variable number of similar setae on anterior and exterior margins. Inner margin of unguis without unpaired teeth (Fig. 20), tenent hair lanceolate. Macrochaetotaxy of Th. 2 and Th. 3 as in Fig. 17, 18. Each lateral anal valve with 2 smooth setae. Male genital plate with about 25 smooth setae arranged in 2 concentric rows. Dorsum of manubrium with 2 parallel rows of 4 + 4 smooth setae (Fig. 22). Dens with 3-5 spines.

HOLOTYPE: Papua New Guinea: Wau, route to Mt. Kaindi, 2100 m, 8-XI-1978, humus and mosses, L. Deharveng (72).

PARATYPES: Same data as holotype, 2 in alcohol and 1 on slide (71, 73, 74).

Heteromurus (*Alloscopus*) *multispinatus* MARI MUTT, 1982

This species was described from two specimens collected in Muller Plateau, SE Papua New Guinea. The collections under study consists of 100 specimens from 12 localities spread across the main island of Papua

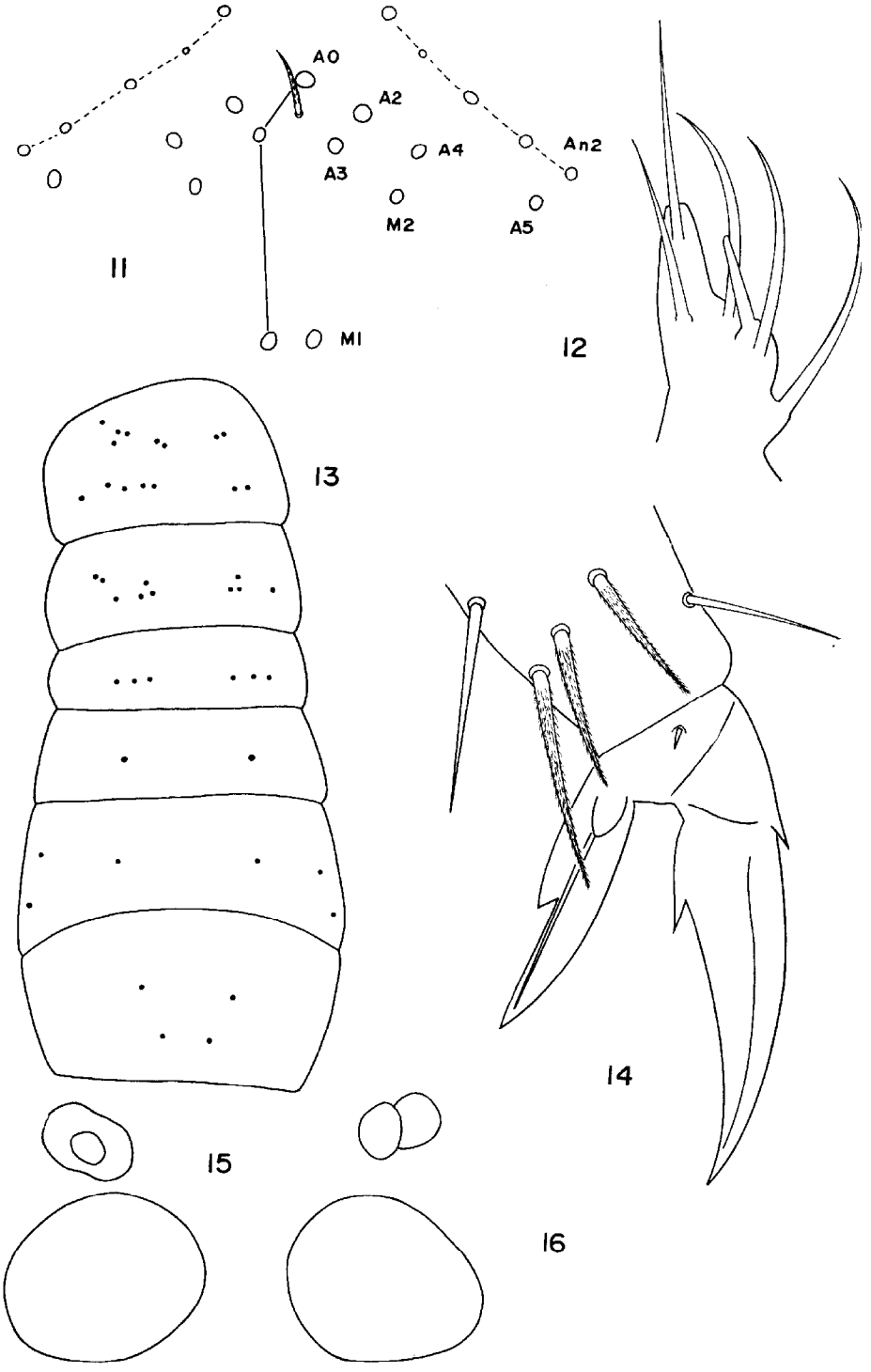

Fig. 11-16. *Heteromurus* (*Alloscopus*) *yosiius*, n. sp. 11. Macrochaetotaxy of anterior portion of head, letters as in Fig. 1. 12. Outer labial papilla. 13. Body macrochaetotaxy. 14. Claws. 15-16. Postantennal organ and eye.

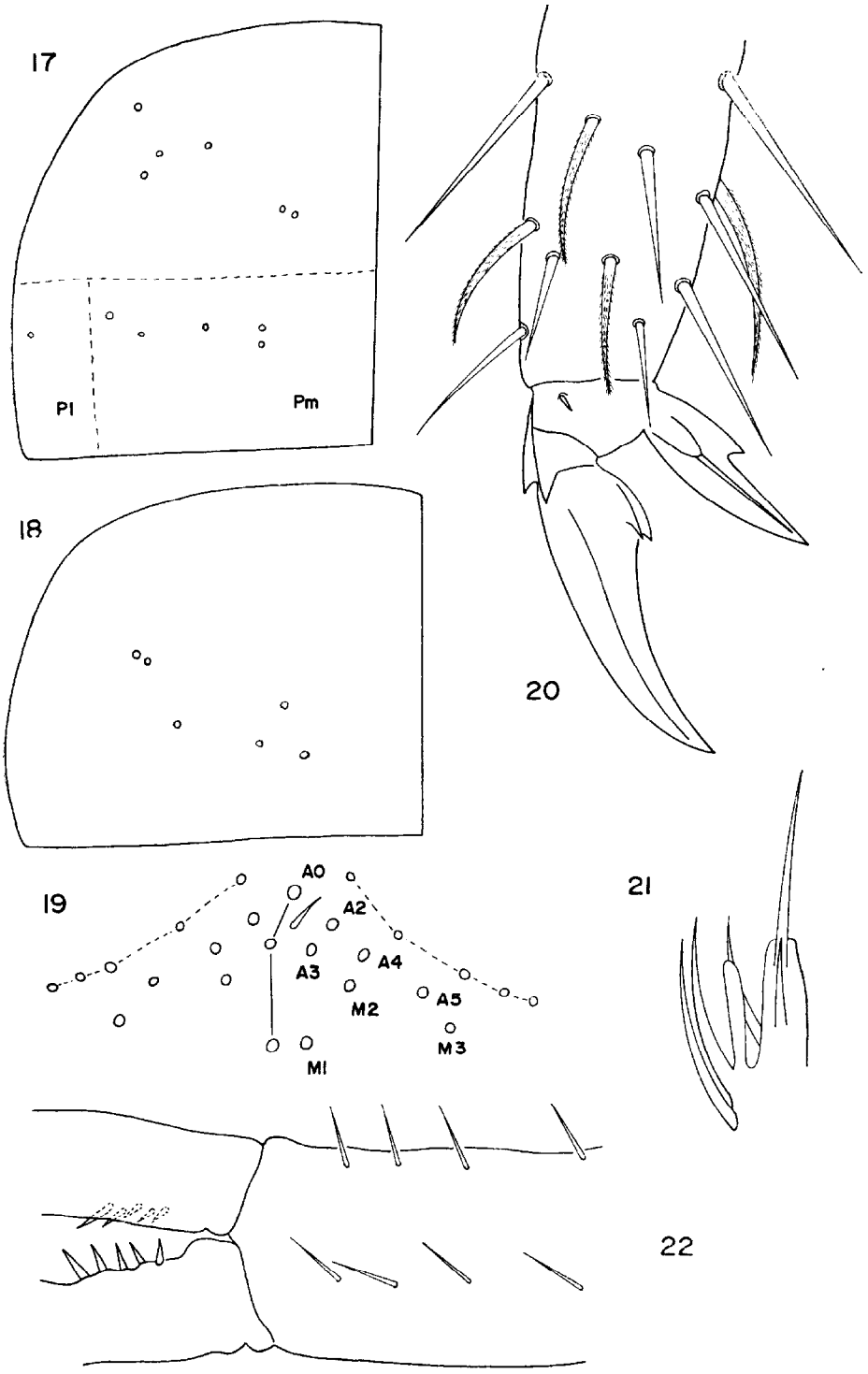

Fig. 17-22. *Heteromurus* (*Alloscopus*) *deharvengi*, n. sp. 17. Macrochaetotaxy of Th. 2, letters as in Fig. 2. 18. Macrochaetotaxy of Th. 3. 19. Macrochaetotaxy of anterior portion of head, letters as in Fig. 1. 20. Claws and smooth setae of tibiotarsus. 21. Outer labial papilla. 22. Dorsum of manubrium and proximal portion of dentes.

New Guinea. The following remarks are based on a detailed study of 12 specimens from localities 69, 273 and 277.

Length to 2.3 mm. Eyes 1 + 1, sometimes surrounded by dark-red or black pigment. Apex of Ant. 5 with slender pin seta and an apically rounded sensilla (Fig. 24). Arrangement of A and M macrochaetae as in Fig. 25; A5 and M3 present, $\bar{x}$ M1-A3/A3-A0 = 1.0 (0.9 — 1.2, n = 10). Length of postantennal organ about 2.6x socket diameter of macrochaeta An2. Outer labral papillae conelike but not sharply pointed like inner papillae (Fig. 27). Posterior portion of labium internal to seta e with 1 ciliated seta, 2 smooth setae and 3-4 scales (Fig. 26); setae e and 1_2 smooth, 1_1 smooth or ciliated. Trochanteral organ with 30-41 smooth setae. Inner margin of unguis with pair of large basal teeth and 0-1 unpaired tooth. Lateral anal valves with 0-1 smooth seta. Male genital plate with about 40 smooth setae arranged in 2-3 concentric rows. Dorsum of manubrium with 2 rows of 3 + 3 or 4 + 4 smooth setae (Fig. 28). Dens with 27-55 spines arranged in 2 rows.

The trochanter is absent on 1 metathoracic leg of 1 specimen (Fig. 23). The "femur" bears the setae of the trochanteral organ but their arrangement is not that of a normal trochanter.

DIAGNOSIS: The presence of 2 rows of dental spines with up to 55 spines total separates this species from the other members of the subgenus, which carry no more than 10 spines arranged always in a single row.

SPECIMENS EXAMINED: Papua New Guinea: Musgrave River, south of Port Moresby, 6-XI-1978, L. Deharveng, 6 in alcohol and 2 on slides (23, 25). Wau, route to Mt. Kaindi, summit, 2400 m, 8-XI-1978, mosses, litter and humus, L. Deharveng, 41 in alcohol and 8 on slides (68, 69, 70). Wau, Bulldog Rd., leaf litter, L. Deharveng, 18 on alcohol and 4 on slides (256, 262, 271, 273, 275, 277, 278). Finschaffen, 16-20-XII-1978, leaf litter, L. Deharveng, 1 in alcohol and 1 on a slide (314). Tsenga, upper Jimmi Valley, 1200 m, 14-VII-1955, grass straw, J. L. Gressitt, 4 in alcohol and 2 on slides. Swart Valley, Knagami, 19-XI-1958, moss, J. L. Gressitt, 1 on a slide. North side of Mt. Gilure, 2500 m, 25-V-1961, malgi moss, M. and L. Gressitt, 2 on slides. Mt. Otto, 2500 m, 22-VI-1955, humus, J. L. Gressitt, 1 in alcohol and 1 on a slide. Daulo Pass (Asaro-Chimb . . .), 2600 m, 14-VI-1955, moss and humus, J. L. Gressitt, 1 on a slide. Mt. Kaindi, 2350 m, VIII-1977, litter, 3 in alcohol and 1 on a slide. Star Mountains, Sibil Valley, 1250 m, 15-20-X-1961, litter, L. and S. Quate, 2 on slides, Mt. Wilhelm, 4260-4694 m, 24-X-1975, P. Beron, 1 on a slide.

Heteromurus (*Alloscopus*) *tetracanthus* BÖRNER, 1906

This species was described originally from Java and has since been recorded from the Philippine island of Luzon, Malaysia, Singapore, India, New Britain, Australia (Queensland), Samoa and Micronesia. Mari Mutt (1978) suggested that the Philippine records of Gapud (1971) belong to *H.* (*A.*) *tenuicornis* Börner and this opinion is supported by the present study of numerous specimens from the islands of Luzon and Mindoro.

Yosii's (1959) records from Malaysia (Malaya) and Singapore are doubtful because his specimens have a different chaetotaxy on Th. 2. *Heteromurus* (*Alloscopus*) *deharvengi* and *H.* (*A.*) *thailandensis* have the chaetotaxy of Yosii's specimens but only the former has smooth setae on the

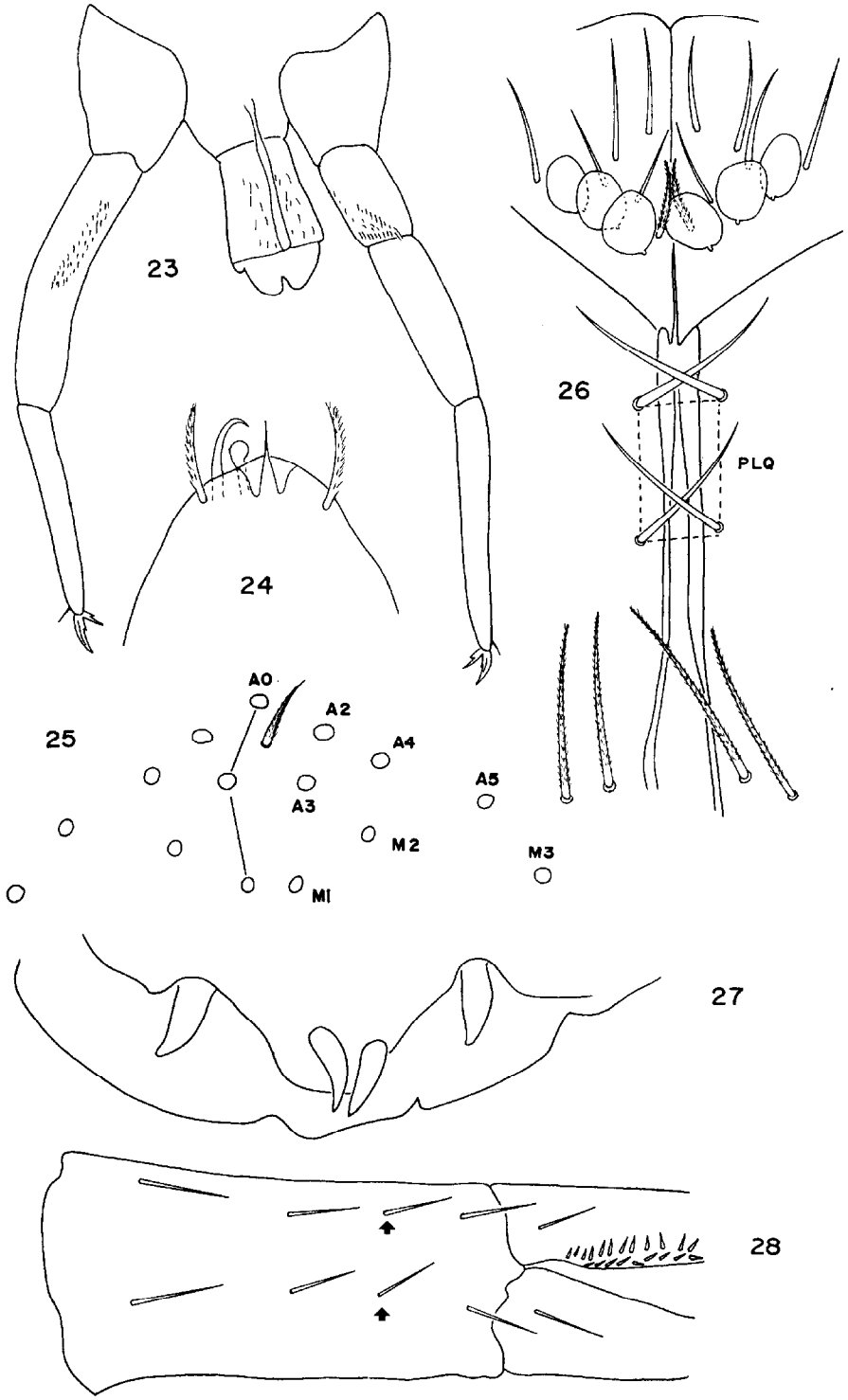

Fig. 23-28. *Heteromurus* (*Alloscopus*) *multispinatus* Mari Mutt. 23. Abnormal and normal metathoracic legs, note different arrangement of trochanteral organ setae. 24. Apex of Ant. 5. 25. Macrochaetotaxy of anterior portion of head, letters as in Fig. 1. 26. Labium and setae along cephalic groove, PLQ = postlabial quadrangle. 27. Labral papillae. 28. Dorsum of manubrium and proximal portion of dentes, setae with arrows are absent in some specimens.

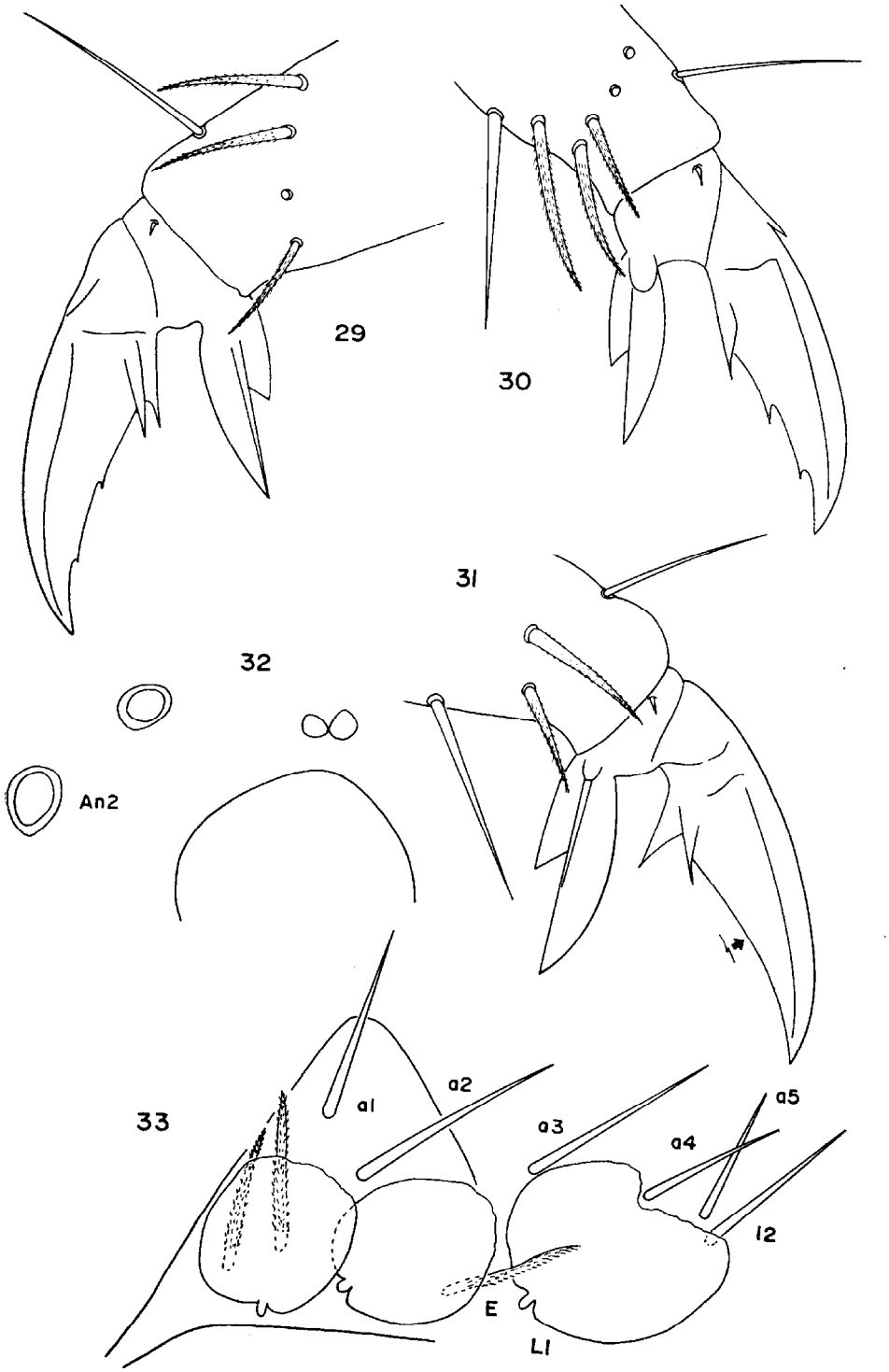

Fig. 29-33. *Heteromurus* (*Alloscopus*) *tenuicornis* Börner. 29-31. Claws, arrow in Fig. 31 indicates position of occasional unpaired tooth. 32. Postantennal organ, eye, and 2 adjacent An macrochaetae. 33. Labial chaetotaxy; a = anterior, E = external, L = lateral, smallcase for smooth setae, capitals for ciliated setae. Note presence of a scale in position of L_1.

tibiotarsi. It is very likely that Yosii's specimens belong to *H. deharvengi* or to a new species closely related to this one. The record from New Britain (Yosii 1960) demands verification because the specimens are from Rabaul, and 1 individual from Rabaul in the present collection belongs to *H.* (*A.*) *tenuicornis.*

Postantennal organ (unrecorded previously for this species) bean-shaped, small, its length about 1.1x socket diameter of macrochaeta An2. Head macrochaeta A5 present, $\bar{x}$ M1-A3/A3-A0 = 1.7 (n = 3: 1.60, 1.69, 1.74). Posterior portion of labium internal to seta e with 1 ciliated seta, 2-3 smooth setae and sometimes a small scale; setae e, 1_1 and 1_2 smooth. Inner margin of ungues with 0-2 unpaired teeth.

DIAGNOSIS: The only other species of the subgenus with smooth setae on the tibiotarsi is *H.* (*A.*) *deharvengi,* and its diagnosis separates it from *tetracanthus.*

SPECIMENS EXAMINED: Papua New Guinea: Lae, 10m, P. Beron, 1 in alcohol and 6 on slides.

Heteromurus (*Alloscopus*) *tenuicornis* BÖRNER, 1906

This species was described originally from Java and has since been recorded from Sumatra, the Philippine island of Luzon, Micronesia and Hawaii. The following observations are based on specimens from the Philippine Islands (Luzon and Mindoro) and Papua New Guinea (New Britain and New Ireland).

Apex of Ant. 5 without pin seta, sometimes with a hooked seta and an apically rounded papilla. Postantennal organ (unrecorded previously for this species) bilobed, small, subequal in length to socket diameter of macrochaeta An2 (Fig. 32). Eyes 1 + 1 or absent. Head macrochaeta A5 present, M3 absent. Mean of distance M1-A3/A3-A0 = 3.0 (2.5 — 3.9, n = 11). Posterior portion of labium internal to seta e with 1-2 ciliated setae, 0-1 smooth seta and 2 scales; seta e ciliated or smooth, L_1 substituted by a scale (Fig. 33), 1_2 smooth. Setae of PLQ smooth or ciliated. Second thoracic segment with a posterolateral (Pl) macrochaeta. Inner margin of unguis with 0-2 unpaired teeth. Manubrium with variable number of smooth setae.

The specimens from the Philippine Islands can be separated into 2 groups. Individuals from localities 17, 18, 20, 26, 28, 20, 42 and 47 possess 2 ciliated setae on the posterior margin of the labium (Fig. 33); seta E, the setae of the PLQ, and all other setae on the venter of the head are ciliated, and there are none or 1 + 1 smooth setae on the dorsum of the manubrium. Specimens from localities 5, 7, 21, 115, 118, 119 and 120 have only 1 ciliated seta on the posterior portion of the labium; seta e, the setae of the PLQ and all other setae on the venter of the head are smooth, and the dorsum of the manubrium carries 2 rows of 4 + 4 smooth setae. Specimens of both groups were found with 0-2 unpaired inner ungual teeth (Fig. 29-31).

DIAGNOSIS: Although different populations of this species exhibit considerable variation in number of teeth on the inner margin of the unguis, and in the chaetotaxy of labium, venter of head, and manubrium (see above), this species can be recognized by the presence of 6 Th. 2 Pm macrochaetae, labial seta L_1 substituted by a scale, $\bar{x}$ M1-A3/A3-A0 = 3.0 (2.5 or less in the other species) and by the long and sharply pointed inner pair of ungual teeth.

SPECIMENS EXAMINED: Philippines, Mindoro, Puerto Galera, nr. San

Theodoro cascade, 2-4-I-1979, leaf litter, L. Deharveng, 15 in alcohol and 2 on slides (5). As preceding but nr. Gulf of Tabinay, 27-29-XII-1979, leaf litter, L. Deharveng and J. Orousset, 3 in alcohol and 2 on slides (115). As preceding but nr. 300 m, litter and humus in primitive forest, 18 in alcohol and 7 on slides (118, 119, 120). Luzon, Mountain Prov., Ambasing, 1440 m, nr. a spring, 16.XII.1979, mosses and leaf litter, L. Deharveng and J. Orousset, 25 in alcohol and 10 on slides (17, 18, 20, 21). As preceding but 1460 m, 10 in alcohol and 3 on slides (26, 28, 30). Luzon, nr. Sagada, by the road nr. Latan cave, 15-19-XII-1979, humus, L. Deharveng and J. Orousset, 8 in alcohol and 3 on slides (42). NE of Sagada, 21-XII-1979, rotten banana plant, L. Deharveng and J. Orousset, 4 in alcohol and 2 on slides (77). Papua New Guinea, New Britain, Rabaul, at sea level, 20-VII-1979, soil under dead trees and coconut palms, J. D. Bourne, 2 on slides (60/79, 61/79). New Ireland, Kavieng, at sea level, 29-VII-1979, soil under Banyan, J. D. Bourne, 2 on slides (104/79).

Key to the Species of *Heteromurus* (*Alloscopus*)

1. Th. 2 with 6 Pm macrochaetae; labial seta L_1 substituted by scale (Fig. 33); $\bar{x}$ M1-A3/A3-A0 = 3.0 ..... *tenuicornis* Börner
1′. Th. 2 with 4 or 5 Pm macrochaetae; L_1 smooth or ciliated but never a scale; $\bar{x}$ M1-A3/A3-A0 < 2.5 2
2(1′). Th. 2 with 4 Pm macrochaetae 3
2′. Th. 2 with 5 Pm macrochaetae 4
3(2′). Inner margin of tibiotarsi with 2 longitudinal rows of smooth setae; head macrochaeta M3 present; labium with 0-1 scale; 1_1 smooth; each lateral anal valve with 2 smooth setae ..... *tetracanthus* Börner
3′. Tibiotarsi without smooth setae; head macrochaeta M3 absent; labium with 2-4 scales; L_1 ciliated; lateral anal valves with 0-1 smooth seta ..... *yosiius* n. sp.
4(2′). Dens with 27-55 spines arranged in 2 rows; Th. 3 with 7 macrochaetae ..... *multispinatus* Mari Mutt
4′. Dens with 3-5 spines arranged in 1 row; Th. 3 with 6 macrochaetae 5
5(4′). Tibiotarsi with several rows of smooth setae; each lateral anal valve with 2 smooth setae; outer pair of labral papillae strongly conelike ..... *deharvengi* n. sp.
5′. Tibiotarsi and lateral anal valves without smooth setae; outer pair of labral papillae rounded, with small lateral conelike projections (Fig. 7, 8) ..... *thailandensis* n. sp.

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SCIENTIFIC NOTES

EUSEIUS MESEMBRINUS (ACARI:PHYTOSEIIDAE): A NEW RECORD ON FLORIDA CITRUS AND LITERATURE CORRECTION

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In Florida, extensive survey and taxonomic studies of phytoseiid mites on various host plants and different prey species have been conducted on citrus (Chant and Baker 1965, Muma and Denmark 1969, Denmark and Muma 1970, 1972, 1975, 1978, Matthysse and Denmark 1981, McMurtry 1983). Fifty-five species of phytoseiid mites have been recorded on various hosts (Denmark and Muma 1967, Muma and Denmark 1970). Muma (1975) listed 38 ambliseiine and phytoseiine mite species, belonging to 19 genera associated with Florida citrus.

In a survey for phytoseiid mites conducted during the summer of 1983 in the vicinity of Lake Alfred, FL., Polk Co., the known predator, *Euseius mesembrinus* (Dean), was collected for the first time from citrus foliage in association with the citrus red mite, *Panonychus citri* (McGregor), and the six-spotted mite, *Eotetranychus sexmaculatus* (Riley). *E. mesembrinus* was widely distributed on citrus foliage collected from numerous groves and was generally found in association with *Amblyseius peregrinus* (Muma), *Typhlodromina subtropica* Muma and and Denmark, *Iphiseiodes quadripilis* (Banks) and *Fundiseius morgani* Chant, all phytoseiid mites of various citrus-inhabiting arthropods.

Initially, taxonomic studies indicated that *E. mesembrinus* was indeed a new species based on the length of the cervix of the spermatheca. However, additional measurements of both the new material from Florida and paratypes of *E. mesembrinus* showed enough overlap in spermathecal length to conclude they were *E. mesembrinus* only. Unfortunately, Browning (1983) prematurely recognized the new mite from Florida as identical to a phytoseiid collected most commonly in a citrus survey in Texas and cited it as *Euseius denmarki* sp. N., Rakha and McCoy based on earlier communication with the authors. This note corrects this error in the literature.

E. mesembrinus was first described from Texas feeding on *Oligonychus pratensis* (Banks) taken from corn. The phytoseiid mite was an effective predator working almost exclusively under the webs formed at the base of the leaves (Dean, 1957). Browning (1983) recovered the mite from at least one location during every month of the year on Texas citrus indicating long-term stability of the species.

One can only speculate as to how and when *E. mesembrinus* became established on Florida citrus. It would appear that establishment has been within the last 10-15 years since Muma conducted extensive surveys for phytoseiid mites on Florida citrus throughout the 1960's. In view of the frequent movement of citrus plantings from Texas to Florida during the past decade, it is very likely that *E. mesembrinus* was an innocuous hitchhiker.

The authors wish to thank Mr. H. A. Denmark, Chief of the Bureau of Entomology, Florida State Collection of Arthropods (FSCA), Florida Department of Agriculture and Consumer Services, Gainesville, FL, Dr. J. A. McMurtry, Professor, Division of Biological Control, University of California, Riverside and Dr. C. C. Childers, University of Florida, Citrus Research and Education Center, Lake Alfred, FL for their contributions to this study.

Florida Agricultural Experiment Station Journal Series No. 5251.

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RADIOISOTOPE LABELLING OF MOLE CRICKETS

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Mole crickets of the genus *Scapteriscus* have become serious pests of turf and pasture grasses in Florida since their introduction into the southeastern U.S. in the late 1800's (Walker and Nickle 1981). One major obstacle to the study of mole cricket ecology and behavior has been the inability to follow their movements underground. Marking with radioisotopes is the most promising method of tracking insects underground, although the shielding effects of soil place some restrictions on isotope selection—only gamma radiation of fairly high energy (above .5 MeV) can be detected consistently through the 15-20 cm of soil used in mole cricket studies (Fuller et al. 1951). Cesium-137 (.663 MeV) satisfies this requirement, and this note reports data on the consumption and persistence of Cs-137 in two pest species, *Scapteriscus vicinus* and *S. acletus*.

Twenty adult females of each species were placed individually into sand-filled 16 oz plastic cups with perforated lids. Ten of each species were controls; the rest were fed the isotope.

One microcurie (μCi) of Cs-137 in 1 M HCl was diluted with distilled water to produce 2 ml of solution. Each of 20 kernels of Grape-Nuts® cereal was then placed in 0.1 ml of the isotope solution, and the liquid allowed to evaporate overnight. One radioactive kernel was placed in the cup with each test cricket. After the isotope was consumed, all crickets (test and control) were fed untreated Grape-Nuts® for the duration of the experiment.

Radioactivity of test crickets was measured in the laboratory daily for 10 days beginning 24 hrs after initial feeding and again on the 14th day, using a laboratory radiation counter and single channel NaI crystal scintillation detector. Measurements were taken by placing crickets individually in a 60 x 15 mm plastic petri dish and putting the dish on a stage ca. 1 cm beneath the fixed probe.

The isotope had no apparent effect on mortality of either species, as 2 *acletus* and 1 *vicinus* died in both test and control groups. Initial activity (counts per minute) averaged 57,982 for *vicinus* (range 23,154-74,753) and 36,665 for *acletus* (range 29,521-65,128).

The decline in radioactivity (as % of first day level) followed a similar pattern for both species (Fig. 1). There was a sharp drop over the first 2 days, probably due to excretion of radioactive material, followed by 4 days when the activity held steady at about 50% of initial count. Another drop occurred between days 6 and 7, and then the activity level remained constant at ca. 10-20% of initial reading for the duration of the experiment.

Cesium-137 has proved useful in monitoring underground movement of mole crickets (Hudson, unpublished data). Holding the test crickets for 48 hrs after feeding before introduction into the experimental arena allows for elimination of most of the isotope that is going to pass through the insect, minimizing contamination of the soil. This leaves about 4 days of fairly uniform radiation from the insects. Trials conducted by placing labelled crickets in buckets of soil indicate radiation in the 15,000-20,000 cpm range is de-

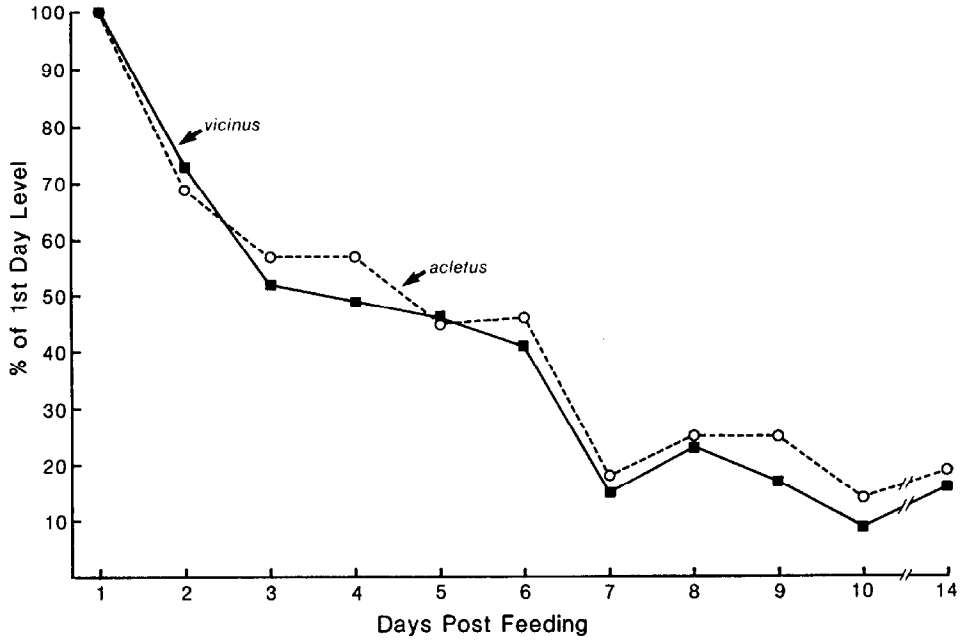

Fig. 1. Mean radioactivity (as % of first day level) of *S. vicinus* and *S. acletus* after consumption of Cs-137.

tectable through 15-20 cm of soil using a G-M type radiation meter. This is Florida Agric. Exp. Sta. Journal Series No. 5524.

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CONTACT TOXICITIES OF EIGHT INSECTICIDES TO THE WIREWORM *MELANOTUS COMMUNIS* (COLEOPTERA:ELATERIDAE)

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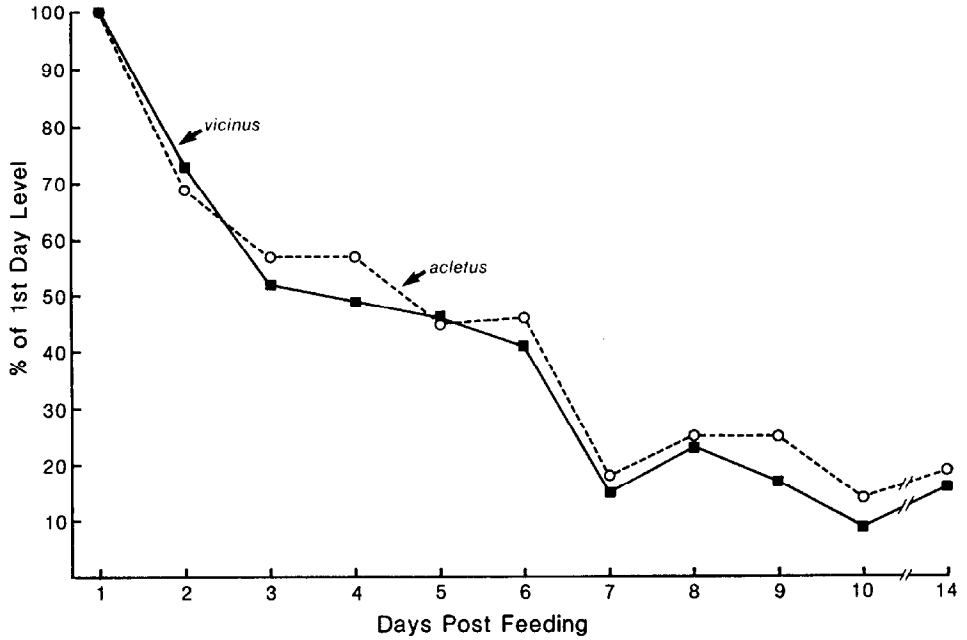
Melanotus communis (Gyllenhal) is the most prevalent wireworm species in south Florida (Wilson 1940) and is an important pest of both vegetable and field crops in this area (Genung 1972). Soil insecticides are commonly



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Melanotus communis (Gyllenhal) is the most prevalent wireworm species in south Florida (Wilson 1940) and is an important pest of both vegetable and field crops in this area (Genung 1972). Soil insecticides are commonly

used in many crops to prevent damage by *M. communis*. Comparative tests have not been conducted on the toxicity of different insecticides to *M. communis*, probably due to the difficulties involved in obtaining a large number of wireworms needed for such tests. In this study, we evaluated the contact toxicities of eight insecticides to *M. communis* wireworms.

Wireworms used in the study were hand-collected from sugar cane fields in south Florida during November 1983 through January of 1984. The average weight of individual wireworms was 0.047 g (s = 0.029). The eight insecticides evaluated (carbofuran, chlorpyrifos, ethoprop, fensulfothion, fonofos, isofenphos, parathion, and phorate) were technical grade materials. Acetone-insecticide solutions (1 µl/wireworm) of various concentrations were topically applied to the dorsal thorax of wireworms using a mircosyringe. Acetone, applied to wireworms as a control treatment, did not induce mortality by itself. During early November, an initial screening of each insecticide was conducted to determine doses that caused between 0 and 100% mortality. Thereafter, 25 wireworms were treated at each of 10 doses around the LD_{50} value for each insecticide. Two doses of each insecticide were tested simultaneously during mid-November, early December, late December, early January, and late January (doses were selected as the study progressed). Wireworms treated with each dose of each insecticide were placed together in a 19 x 13 x 8 cm plastic pan containing muck soil (85% organic) and carrots for food. Wireworms were then maintained in constant darkness at 25°C for 2 weeks (based on the initial screening, it sometimes required 14 days for insecticides to cause mortality). At the end of each test, the number of dead wireworms/dose was counted. Wireworms were considered dead if they displayed no movement when prodded. The data were subjected to probit analysis (Barr et al. 1979) to determine the LD_{50} value, 95% confidence interval, and slope values for each insecticide.

Each of the eight insecticides was toxic to *M. communis* wireworms. LD_{50} values indicated parathion was the most toxic insecticide to *M. communis* larvae, followed by fensulfothion, carbofuran, phorate, ethoprop, isofenphos, fonofos, and chlorpyrifos, respectively (Table 1). Based on 95% confidence intervals around the LD_{50} values, the toxicity of parathion was significantly greater than the toxicities of the other 7 insecticides. Overlapping

TABLE 1. CONTACT TOXICITIES OF EIGHT INSECTIDES TO *M. communis* WIREWORMS.

Insecticide	LD_{50} value[1]	95% Confidence interval	Slope[2]
Parathion	0.13	0.10-0.17	1.68
Fensulfothion	0.38	0.20-0.82	1.57
Carbofuran	0.79	0.41-1.74	1.40
Phorate	0.81	0.64-1.03	1.73
Ethoprop	0.87	0.44-2.00	1.13
Isofenphos	0.89	0.62-1.40	1.04
Fonofos	1.25	0.77-2.18	1.76
Chlorpyrifos	2.57	1.98-3.42	2.70

[1]µg/wireworm.
[2]Increase in probit mortality per 10-fold increase in dosage.

confidence intervals indicated that there were no significant differences among the LD_{50} values for fensulfothion, carbofuran, phorate, ethoprop, isofenphos, and fonofos. Throughout the study, chlorpyrifos was noticeably less toxic to *M. communis* at the LD_{50} level than the other insecticides. Data from this study are useful for selecting toxicants for field evaluations of *M. communis* control. Also, this toxicity test may be repeated to elucidate resistance to insecticides in an *M. communis* population.

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PARASITISM OF NYMPHAL *MESOVELIA MULSANTI* (HEMIPTERA: MESOVELIIDAE) BY THE WATER MITE *HYDRYPHANTES TENUABILIS* (ACARIFORMES: HYDRYPHANTIDAE)

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Larvae of the water mite *Hydryphantes tenuabilis* Marshall, a possible synonym of *Hydryphantes ramosus* Daday, are common parasites of the marsh treader *Hydrometra australis* Say (Hemiptera: Hydrometridae) in some geographic regions (Lanciani 1971). Although each of the 5 nymphal instars of this host may bear parasitic mite larvae, the mites feed little if at all on the nymphs and do no apparent harm (Lanciani 1975). However, by well-timed detachment and reattachment, the mites remain with the nymphs through each molt and eventually reach the adult host. Shortly after attachment to the adult host, the larval mites begin to engorge and, within 7-13 days, have metamorphosed to the nymphal stage and detached from the host.

Collections in spring from marshes near Gainesville, Florida revealed that *H. tenuabilis* is found on another surface-dwelling hemipteran, *Mesovelia mulsanti* White, but much less frequently than on *H. australis* from the same marshes. In contrast to the pattern of mite development on *H. australis*, both adults and nymphs of *M. mulsanti* were truly parasitized.

Laboratory rearing experiments confirmed that larval *H. tenuabilis* engorge and metamorphose on adults and each of the 5 nymphal instars of *M. mulsanti*. Offspring of mites reared from *H. australis* adults were observed to engorge on nymphal *M. mulsanti* but not on nymphal *H. australis* even though the latter mites remained alive and continued transferring

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to the next instar after each molt of the host. Thus, the mites parasitizing both host species are obviously of the same species. Engorged mites were found primarily on the host's thoracic and abdominal dorsum. In all rearing experiments, each insect was held alone at 28°C in 100 x 15 mm plastic petri plates lined with moistened, absorbent paper and fed *Drosophila* that were killed by freezing.

The stadia of unparasitized *M. mulsanti* were observed to be consistently longer than those of unparasitized *H. australis* (t-test, $p<0.01$ for each nymphal instar, Table 1). Thus, the physiological states, e.g. hormone levels, of nymphal *M. mulsanti* and *H. australis* may be sufficiently different to promote the developmental difference seen in their parasitic mites. Other parasites are known to be influenced by host physiology (Rothschild and Ford 1972, Baronio and Sehnal 1980). In neither host species was the stadium of any unparasitized nymphal instar long enough to allow larval mites to metamorphose to the nymphal stage. However, in *M. mulsanti*, the mite's engorgement extended the stadia of parasitized insects, e.g. stadia were 7, 8, and 8 days in 3 parasitized individuals of instar 1; 8 days in 2 parasitized individuals of instar 2; and 14 days in 1 parasitized individual of instar 3. Similar water mite-induced delays in host nymphal development have been observed in the notonectid *Buenoa scimitra* Bare (Lanciani and May 1982).

Instars 1 through 4 of *M. mulsanti* were observed in the laboratory to kill and, in many instances, to consume mite larvae that were attempting to or had already managed to attach. Thus, in mites parasitizing *M. mulsanti*, the benefit of an increased rate of development may be offset by the cost due to predation by the host. *Hydrometra australis* nymphs were never observed to prey on mite larvae. The lower observed frequency of parasitized *M. mulsanti* in nature may reflect a more highly developed behavioral defense against parasitic mite larvae.

Other surface-dwelling Hemiptera are hosts of *H. tenuabilis*. A wingless adult of the hebrid *Merragata brunnea* Drake bearing an engorged larva was collected in the field, and an adult *Mesovelia amoena* Uhler was successfully parasitized in the laboratory.

TABLE 1. THE MEAN STADIUM (IN DAYS) PLUS OR MINUS THE STANDARD ERROR OF EACH NYMPHAL INSTAR OF UNPARASITIZED *M. mulsanti* AND *H. australis* REARED UNDER IDENTICAL CONDITIONS. DATA FOR INSTARS 2 THROUGH 5 WERE OBTAINED FROM FIELD-COLLECTED INSTARS 1 THROUGH 4 THAT WERE MAINTAINED IN THE LABORATORY THROUGH THEIR NEXT INSTAR ONLY. DATA FOR INSTAR 1 NYMPHS WERE OBTAINED FROM HATCHED EGGS OVIPOSITED BY FIELD-COLLECTED FEMALES. DATA FOR *H. australis* WERE ORIGINALLY PRESENTED IN LANCIANI (1975).

Instar	*M. mulsanti*		*H. australis*	
	Stadium	Sample size	Stadium	Sample size
1	3.19 ± 0.13	21	2.57 ± 0.05	100
2	2.56 ± 0.12	18	2.19 ± 0.05	96
3	2.88 ± 0.09	16	2.42 ± 0.06	97
4	3.00 ± 0.10	14	2.46 ± 0.05	99
5	3.64 ± 0.10	22	3.23 ± 0.04	97

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PAPAYA FRUIT FLY EGGS AND LARVAE (DIPTERA: TEPHRITIDAE) IN FIELD-COLLECTED PAPAYA FRUIT

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The papaya fruit fly, *Toxotrypana curvicauda* Gerstaecker, is a major pest of papaya, *Carica papaya* L., throughout much of the American tropics and subtropics. Although a series of studies was recently completed on adult behavior and life history (Landolt and Hendrichs 1983, Landolt 1984, 1985, Landolt et al. 1985, Sharp and Landolt 1984), little published information exists on the immature stages or the infestability of papaya fruit by papaya fruit flies. In support of an effort to establish a laboratory colony of papaya fruit flies on papaya fruit, an observational study of flies in field-collected fruit was conducted to determine what stages and sizes of papaya fruit were infested. Information also was gathered on the location and numbers of eggs and larvae in fruit to contribute to a more comprehensive life history of the papaya fruit fly.

Infested papaya fruit were obtained from commercial papaya groves in Dade County, Florida and from papaya trees on the grounds of the Subtropical Horticulture Research Station, Miami, Florida. Fruit of all sizes (1.9 to 15 cm diam) were randomly selected, picked, and transported to the laboratory for analysis. Damaged fruit and fruit with holes of any size were excluded from analysis, as were ripe fruit that may have been host to other species of fly larvae.

In the laboratory, fruit were first cut in half, fruit diameter and pulp thickness were measured, and fruit condition and any abnormalities were recorded. Fruit were then thoroughly dissected and searched for papaya fruit fly eggs and larvae. Fruit remnants were soaked in water overnight to drive any remaining small larvae from the pulp so they could be collected. Records were made of the location of eggs and larvae within the fruit, feeding and burrowing activity of larvae and sizes and numbers of larvae and eggs in each fruit. Identifications and measurements of eggs and larvae were made under a binocular dissecting microscope with the aid of an

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ocular micrometer. All measurements were made at 10X magnification while specimens were immersed in 80% ethanol.

Of 205 infested fruit analyzed, 44 contained papaya fruit fly eggs. Eggs appeared as described by Knab and Yothers (1914), but were often linked end-to-end in strings (13/44 fruit) or in clumps (14/44 fruit) as reported by Mason (1922). The number of eggs per string or clump, indicative of a single oviposition bout by a female, ranged from 2 to 30. Numbers of eggs per fruit ranged from 1 to 30 ($\bar{x} \pm$ S.E. = 10.1 $\pm$ 8.7, n = 44). In 28 fruit with eggs, from 1 to 42 larvae were present also. Larvae in such fruit ranged from newly hatched to mature (from 0.65 to 12.3 mm long). The greatest number of eggs and larvae found together was 51. Eggs were found only within the seed cavity, either between or on immature seeds. Eggs were found in papaya fruit ranging from 1.9 to 10.9 cm (4.6 $\pm$ 1.7, n = 44) diam with pulp thicknesses (from the skin to the wall of the seed cavity) of 0.3 to 1.8 cm.

Papaya fruit fly larvae were found in 187 of the 205 infested fruit. From 1 to 56 were found per fruit, with an average of 15.1 (S.E. = 10.9) per fruit. Infested fruit ranged in size from 1.9 to 12.8 cm diam with pulp thicknesses of 0.2 to 2.0 cm. The complete range of sizes of fruit sampled was 1.9 to 15 cm diam with 0.2 to 2.5 cm thick pulp. Sixteen of 187 fruit infested were beginning to ripen, as indicated by yellow areas on the fruit exterior. Average length of larvae in this fruit (11.5 cm) was significantly greater than that of larvae in green fruit (7.7 cm) (1% level by Student's *t*-test). No eggs were found in fruit beginning to ripen. As reported by Mason (1922) and Knab and Yothers (1914), young larvae were found feeding on the seeds, usually within a small area of browned seed embryos; mature larvae were found tunnelling within the pulp, often near the exterior surface of the fruit.

Observations reported here indicate that the infestability of papaya fruit by papaya fruit flies may be limited by the depth of the fruit pulp. Fresh ovipositions in green fruit are outwardly visible as hardened mounds of sap on the surface (Landolt and Hendrichs 1983). In dissected fruit, the piercing of the pulp by the fruit fly ovipositor was often visible as a browning of the tissue within 2 mm of the path of the ovipositor through the pulp and by mounds of solidified sap exuded from the wound into the seed cavity. Similar wounds that did not run completely through the fruit pulp were often observed; possible evidence of an unsuccessful oviposition attempt. The absence of eggs in fruit with pulp greater than 1.8 cm in thickness suggests this may be a limiting function. Also, ovipositors of 10 field-collected female papaya fruit flies had an average length of 1.68 cm (S.E. = .09) and a maximum length of 1.85 cm, corresponding to the maximum pulp depth through which eggs were deposited.

This observed coincidence of a certain pulp thickness, presence or absence of eggs, and the length of the ovipositor indicates that female papaya fruit flies do not successfully infest fruit if they cannot get through the pulp to place eggs in the seed cavity. It is not known if this is caused by a failure to deposit eggs under those conditions, or if the eggs do not survive when placed in the pulp of the papaya fruit. Knab and Yothers (1914) found that "thick-meated" fruit were not infested and suggested a link between this and groves of particular varieties that appeared to be free from infestation. However, as pointed out by Wolfen-

barger (1962), fruit of all varieties are thin-fleshed when young and are thus susceptible to infestation. Because fruit that escape infestation will grow to full size and maturity, harvested fruit of these larger varieties would tend to be uninfested. Since infested fruits often ripen prematurely and fall from the tree, an infestation could exist in such groves but remain undetected.

Although Mason (1922) stated that "usually an adult fly will not oviposit in a fruit with eggs or larvae," field-infested fruit was collected that contained both eggs and larvae (28), indicating otherwise. These were undoubtedly separate, temporally spaced ovipositions in the same fruit.

It appears then, that, unripe papaya fruit can be infested with papaya fruit flies if the female can completely penetrate the pulp with her ovipositor, regardless of the presence or absence of other eggs or even larvae already in the fruit. Since no evidence of cannabilism by larvae was observed, it is not known what regulates numbers of larvae in papaya fruit.

Technical assistance was provided by R. Renfro. Roy Nelson generously provided a supply of papaya fruit and allowed the use of his papaya grove for these studies.

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THE SUGARCANE DELPHACID, PERKINSIELLA SACCHARICIDA (HOMOPTERA:DELPHACIDAE), A SUGARCANE PEST NEW TO NORTH AMERICA DETECTED IN FLORIDA (UNA PLAGA DE LA CAÑA DE AZÚCAR NUEVA PARA NORTEAMÉRICA DETECTADA EN LA FLORIDA)

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I discovered the sugarcane delphacid (*Perkinsiella saccharicida* Kirkaldy), an exotic pest of sugarcane, on August 4, 1982 in a sugarcane field approximately 22 km west of West Palm Beach, Florida. This insect was not previously known to occur in North America. Identification was made on September 15, 1982 by James P. Kramer (USDA Systematic Entomology Lab., U.S. National Museum, Washington, DC). *P. saccharicida* originally occurred in Java, Formosa, southern China, the Malay States and Australia. It has been introduced into the Hawaiian Islands, Mauritius, Reunion, Madagascar, and South Africa (Fennah 1969). In the Western Hemisphere, Risco (1969) reported it in Ecuador on June 15, 1966, and in Peru on October 3, 1967.

Sugarcane delphacids were in every sugarcane field surveyed in Glades, Hendry, Martin, and Palm Beach counties on September 21, 1982. Sugarcane delphacids were counted on 10 shoots each in 23 fields throughout Florida's sugarcane growing region (147,750 ha). A mean of 9 sugarcane delphacids/shoot were counted ranging from 0.5/shoot in one field to 35.7/shoot in another field. Sugarcane delphacids were observed on 94% of all shoots inspected. Egg masses were counted on all leaves from 25 shoots (ca. 60 cm high) in one 8-week-old sugarcane field. A mean of 273 egg masses/shoot was counted on 183 leaves ($\bar{X}$ = 7.3 leaves/shoot). Also, eggs in 100 egg masses were counted giving a mean of 4.5 eggs/egg mass. Therefore, population levels of 1228 sugarcane delphacids/shoot were possible. Since the highest number of sugarcane delphacids/shoot observed during the survey was 51, it appeared that egg hatch and/or first instar nymphal mortality was very high, with the result that nymphs were hard to find in fields even where heavy oviposition was observed. This is in apparent agreement with Bull (1981), who reported a small population of presumed 4th generation adults that became rare during the winter.

Biological control by the egg predator *Tytthus mundulus* (Breddin) (Hemiptera:Miridae), is credited with keeping sugarcane delphacid populations at such low numbers that it is not now a threat to sugarcane in Hawaii, Fiji, and Mauritius (Carnegie and Harris 1969). Due to this success a cooperative effort was undertaken by the Hawaii Department of Agriculture, the Division of Plant Industry (DPI) of the Florida Department of Agriculture and Consumer Services, and the USDA's APHIS and ARS to import *T. mundulus* into Florida. Releases were made December 20, 1982 and April 8, 1983, in a field at the USDA Sugarcane Field Station, Canal Point, Florida. Two releases were made in a commercial field ap-

proximately 16 km southeast of Canal Point, Florida, on August 23 and September 13, 1983. It is not known whether *T. mundulus* has become established.

Two biological control organisms have been collected in Florida from sugarcane leaves infested with sugarcane delphacids. I collected the egg parasite *Anagrus* sp. on September 25, 1982 (identified by L. A. Stange, DPI). Two species, *A. obtabilis* (Perkins) and *A. frequens* (Perkins), are recorded as egg parasites of the sugarcane delplhacid, but taxonomy of this genus is poorly understood and positive identification was not possible (pers. comm. Lloyd Knutson, USDA, ARS, Insect Ident. and Beneficial Insect Introd. Inst., Beltsville, MD). *Tytthus parviceps* (Reuter), an egg predator, was collected by Ru Nguyen (DPI) on October 13, 1982 and identified by T. J .Henry (USNM). Another mirid, *Cyrtorhinus pellicia* (Uhler) was observed in 1937 by Ingram *et al.* (1939) ovipositing in an egg cluster of *Saccharosydne saccharivora* (Westwood) (Homoptera:Delphacidae). Thus, at least two egg predators and one egg parasite of this pest are known to be already established in Florida, possibly on eggs of *S. saccharivora* (Westwood) before the introduction of the sugarcane delphacid.

The sugarcane delphacid is a vector of Fiji disease, a major viral disease of sugarcane. Fiji disease is presently restricted to the South Pacific, S.E. Asia, and Madagascar (Antoine 1967). Although Fiji disease has not been found in the Western Hemisphere, the presence of the vector now makes its introduction and establishment more likely. Therefore, there is need to keep the vector population at the lowest level possible.

Yo descubrí a *Perkinsiella saccharicida* Kirkaldy, una nueva plaga de la caña de azúcar, en un campo de caña de la Florida el 4 de agosto de 1982 aproximadamente a 22 km al oeste de West Palm Beach, Florida. Este insecto no era antes conocido en Norteamérica. La identificación fue hecha el 15 de septiembre de 1982 por James P. Kramer (USDA Systematic Entomology Lab., U.S. National Museum, Washington, DC). *P. saccharicida* estaba distribuida originalmente en Java, Formosa, el sur de China, los Estados de Malasia, y Australia. Ha sido introducida en las islas Hawaii, Mauritius, Reunion y Madagascar, y Africa del Sur (Fennah 1969). En el Hemisferio Occidental, Risco (1969) reportó su presencia en Ecuador el 15 de junio de 1966, y en Perú el 3 de octubre de 1967.

P. saccharicida estaba en todos los campos de caña inspeccionados el 21 de septiembre de 1982 en los condados de Glades, Hendry, Martin, y Palm Beach. *P. saccharicida* fue contada en 10 tallos en 23 campos esparcidos por la región azucarera de la Florida (147,750 ha). Esto arrojó un promedio de 9 *P. saccharicida*/tallo, fluctuando entre 0.5/tallo en un campo, y 35.7/tallo en otro campo. Se observaron *P. saccharicida* en el 94% de todos las tallos inspeccionados. Se contaron las masas de huevos en todas las hojas de 25 tallos (aproximadamente de 60 cm de altura) en un campo de caña de 8 semanas de edad. Se encontró un promedio de 273 masas de huevos/ tallo en 183 hojas ($\bar{X}$ = 7.3 hojas/tallo). También se contaron los huevos en 100 masas de huevos, dando un promedio de 4.5 huevos/masa de huevo. De aquí que niveles de población de 1228 *P. saccharicida* por tallo eran posibles. Puesto que el número más alto observado de *P. saccharicida* por tallo durante la inspección fue de 51, aparentemente la mortalidad de

los huevos al nacer o de las ninfas en el primer estadío fue muy alta, con el resultado de que era difícil de encontrar ninfas en campos donde se había observado una alta postura de huevos. Esto está aparentemente de acuerdo con el descubrimiento de Bull (1981), que reportó sobre una población de adultos que indicaba la presencia de una aparente cuarta generación antes de ser escasa durante el invierno.

Al control biológico del rapaz de huevos *Tytthus mundulus* (Breddin) (Hemiptera:Miridae), se le acredita el mantener la población de *P. saccharicida* en números tan bajos que ahora no es una amenaza para la caña de azúcar en Hawaii, Fiji, o Mauritius (Carnegie y Harris 1969). Debido a este éxito se iniciaron gestiones en cooperación entre el Departamento de Agricultura de Hawaii, la Division of Plant Industry (DPI) de la Florida Department of Agriculture and Consumer Services, y APHIS y ARS del USDA para importar *T. mundulus* en la Florida. Se hicieron liberaciones el 20 de diciembre de 1982 y el 8 de abril de 1983 en un campo de la Estación Experimental de la Caña de Azúcar del USDA en Canal Point, Florida. Se hicieron dos liberaciones en un campo comercial aproximadamente a 16 km al sudeste de Canal Point, Florida, el 23 de agosto, y el 13 de septiembre de 1983. No se sabe todavía si *T. mundulus* se ha establecido.

Se colectaron en la Florida dos organismos de control biológico en hojas infestadas por *P. saccharicida.* Yo coleccioné el parásito de huevos *Anagrus* sp. (Hymenoptera:Mymaridae) el 25 de septiembre de 1982 (identificado por L. A. Stange, DPI). Dos especies, *A. obtabilis* (Perkins) y *A. frequens* (Perkins) se han catalogado como parásitos de los huevos de *P. saccharicida,* pero este género necesita revisión y una identificación positiva no fue posible (comunicación personal con Lloyd Knutson, USDA, ARS, Insect Ident. and Beneficial Insect Introd. Inst., Beltsville, MD). *Tytthus parviceps* (Reuter) (Hemiptera:Miridae), un rapaz de huevos, fue colectado por Ru Nguyen (DPI) el 13 de octubre de 1982 e identificado por T. J. Henry (USNM). Otro mírido, *Cyrtorhinus pellicia* (Uhler), fue observado en 1937 por Ingram *et al.* (1939) poniendo huevos en masas de huevos de *Saccharosydne saccharivora* (Westwood) (Homoptera:Delphacidae). Así que por lo menos 2 rapaces de huevos y un parásito de huevos de esta plaga están establecidos en la Florida possiblemente en huevos de *S. saccharivora* (West wood) previo a la introducción de *P. saccharicida.*

P. saccharicida es un vector de la enfermedad de Fiji, que es una enfermedad viral muy importante de la caña de azúcar. La enfermedad de Fiji está limitada actualmente al Pacífico del Sur, Sudeste de Asia y Madagascar (Antoine 1967). Aunque la enfermedad de Fiji no ha sido encontrada en el Hemisferio Occidental, la presencia del vector hace su introducción y establecimiento más posible. De aquí la necesidad de mantener las poblaciones del vector a los niveles más bajos como sea posible.

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IN MEMORIAM

HAROLD LAVERNE KING

Mr. Harold LaVerne King passed away on 27 January 1985 at his home in Sarasota following an extended illness. A charter member of The Lepidopterists' Society and a Research Associate of the Florida State Collection of Arthropods since 1969, "Verne" collected Lepidoptera as an avocation much of his lifetime with a special interest in Lycaenidae. He made a significant contribution to our knowledge of the Lepidoptera of Florida, other parts of the United States, and especially of Mexico and Central America. His large, neatly prepared, accurately identified collection, which included some very rarely collected Neotropical species, had been deposited in the FSCA prior to his death at the age of 85. Mr. King was a commercial artist and for many years owned and operated King Of Sarasota Advertising Service, which involved a billboard business throughout much of Florida and southern Georgia. He is survived by his wife, Suejette, and 3 children by an earlier marriage: Mrs. Carolyn Clough, Jr., Ms. Polly Ann King, and Mr. William C. King.

Howard V. Weems, Jr.
Taxonomic Entomologist and Curator
Florida State Collection of Arthropods

IN MEMORIAM

DR. GERMAIN C. LABRECQUE

1922-1984

Dr. Germain C. LaBrecque, a well-known USDA retired medical entomologist, died unexpectedly of a stroke in Vienna, Austria, on November fifteenth, 1984. For the past two years he was a coordinator and consultant to the International Atomic Energy Agency, in Vienna Austria, and had been working on a long term Med Fly eradication project with the Egyptian government.

Dr. LaBrecque's lengthy scientific career began shortly after his separation from the Army Air Force at the end of WW II. He attended Tufts University in Medford, Massachusetts where he received his BS in Biology in 1949. Immediately afterwards, he entered the University of Tennessee and obtained his Masters in Entomology in 1950. He joined the USDA in 1951 and began his career as a research entomologist at the Insects Affecting Man and Animals Research Laboratory, in Orlando, Florida. The following year he left for a twelve-month tour in Egypt to work on Sand Flies and other medically important arthropods at the U.S. Navy Research Facility in Cairo.

Upon his return to the States and the USDA facilities in Orlando, Florida, he continued his research program on the biology and control of mosquitoes and flies. This was interrupted to return to academia to complete a Ph.D. in Entomology from Ohio State University in 1957.

Jerry was one of the foremost pioneers in the utilization of the sterile insect technique using both irradiation and chemosterilization methodologies. The practical application of many of his ideas and concepts are now being used successfully in the control of numerous medical and crop arthropod pests throughout the world.

A prolific writer during his thirty-year tour with the USDA, he was author or coauthor of over 200 scientific publications and a book on the principles of insect chemosterilants. He also was an astute preparer of research grants and specially funded projects and was principal investigator on many both here and abroad.

In 1963 the USDA facility was moved from Orlando, Florida to the campus of the University of Florida at Gainesville. Jerry immediately became an adjunct professor in the department of Entomology and Nematology where he served as chairperson and faculty member on several student committees for MS and Ph.D. degrees. His enthusiasm for research was a

constant source of strength to all who were under his directions during this period in Jerry's career. He also served as a member on doctoral examination boards in Universities in Europe, Asia and Australia.

Second to his love for his work and family, Jerry was consumed by his passion for travel and the challenge of working in foreign lands. During his career with the USDA he was involved with numerous insect control studies throughout the Caribbean Basin. In 1963 he spent six months in the Sudan bush and amongst the Masai tribes on a project to control Sand Flies. From 1971 to 1972, Jerry took official leave from the USDA and moved his family to New Delhi, India where he headed up a research laboratory, funded and directed through the World Health Organization and the Indian Council of Medical Research. The object of this project was to determine the economic feasibility of genetically controlling mosquitoes. It had a staff of 21 scientists and 147 support persons. The scientific aspects of the program were very successful and laid the groundwork for future research projects.

In 1978 he was reassigned again overseas, this time to take charge of the Entomology section for the joint FAO/IAEA (International Atomic Energy Agency) Division of Isotope and Radiation Applications of Atomic Energy for Food and Agricultural Development, a position he held until 1982. He was instrumental in initiating several large integrated pest management programs throughout the world. Although he returned briefly to the US in 1982 to retire from the USDA, he quickly returned to Vienna to serve as a consultant to the IAEA/FAO, this time to assist the Egyptian government in setting up an eradication program for the Mediterranean Fruit Fly. His death made this one of the few endeavors Jerry left undone.

His loss was deeply felt in both the scientific and diplomatic communities. This was evident by the many scientists and dignitaries who attended his memorial services both in Vienna, Austria and Gainesville, Florida. His family, and those who worked with Jerry for many years, will always remember his unbounded enthusiasm for life and abiding dedication towards improving the welfare of mankind. His presence among us will be sadly missed.

R. S. Patterson
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