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This issue mailed January 15, 1982

ORIENTATION OF SOUTHERN MOLE CRICKET, *SCAPTERISCUS ACLETUS*, LANDING AT A SOUND SOURCE[1]

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ABSTRACT

Mole crickets, *Scapteriscus acletus*, attracted to a synthetic male calling song, can use visual cues as they end their flight. The insects landed significantly ($P<0.001$) more often on stripes than on a contrasting background. The visual form of the stimulus was more important in attracting mole crickets than the contour (perigrammotaxis) or the low reflectance (scototaxis) of the patterns. In windy weather the proportion of crickets landing on top of the sound source is less.

RESUMEN

Los cortones, *Scapteriscus acletus*, atraidos por la llamada sintética del macho, pueden guiarse visualmente según terminan su vuelo. Significativamente, los insectos aterrizaron ($P<0.001$) más frequentemente sobre las rayas que en el fondo contrastante. La forma visual del estímulo fué de más importancia para atraer los cortones que el contorno ("perigrammotaxis") o el bajo reflejo ("scototaxis") de los patrones. Durante tiempos ventosos, la proporción de cortones que aterrizaron sobre el lugar de origen del sonido fué menor.

Little is known of visual orientation in mole crickets. Pardi (1975) proposed that the European mole cricket, *Gryllotalpa gryllotalpa* (L.), used sun-compass orientation. The European mole cricket and 2 southern United States species, *Scapteriscus vicinus* Scudder and *S. acletus* Rehn and Hebard, are attracted to UV light traps (Hosney and Khattab 1959, Beck and Skinner 1967, Ulagaraj 1975). At Gainesville, Florida, large flights of *S. acletus* occur from April to July ca. 1 hour after sunset (Ulagaraj 1975). This period of flight is correlated with the male calling period (Forrest 1980). Adult mole crickets use the calling song of males, singing in their burrow, to locate possible mates, suitable habitats, or oviposition sites. These different purposes for orientation may cause the insects to end their flights differently. Average landing distances from the sound source are less for females than for males (Ulagaraj 1975) and for crickets (males and females) entering a calling male's burrow than for those that do not (T. G. Forrest, personal communication). Though orientation of flying mole crickets is guided by phonotaxis (Ulagaraj and Walker 1973, 1975), the use of visual cues, another possible means of orientation during landing, has not been investigated nor have the effects of weather on the accuracy of landing in

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relation to the sound source. Information regarding the visual orientation of landing mole crickets may provide insight into their basic behavior and be useful in developing traps for mole crickets landing at simulated male calls.

Material and Methods

All experiments were conducted outdoors from April to June 1980 at Green Acres Farm, University of Florida, 19 km northwest of Gainesville. Wind conditions and air temperatures at 40 cm above the ground were recorded during each observation. Mole crickets were attracted during their early evening flight period by broadcasting a constant artificial *S. acletus* call (2.7 kHz, 50 pulses/s., 106 dB(A) at 15 cm) from a small electronic sound unit. Landings were observed on a wooden horizontal circular platform (diameter 1.2 m) placed around the sound source(Fig. 1). To test for visual preferences, I painted the platform with contrasting alternate stripes (black or white). Mole crickets landing on top of the sound source were captured in a cylindrical screen cage (diameter 20 cm) closed above with a screen funnel (Fig. 1).

Scapteriscus acletus often occurs near the edges of lakes, ponds and streams (Ulagaraj 1975). Therefore, a wading pool (diameter 1.5 m) divided into 4 equal parts (2 containing sand and 2 with water), with the sound unit in the center, was used to study landing preferences on sand versus water.

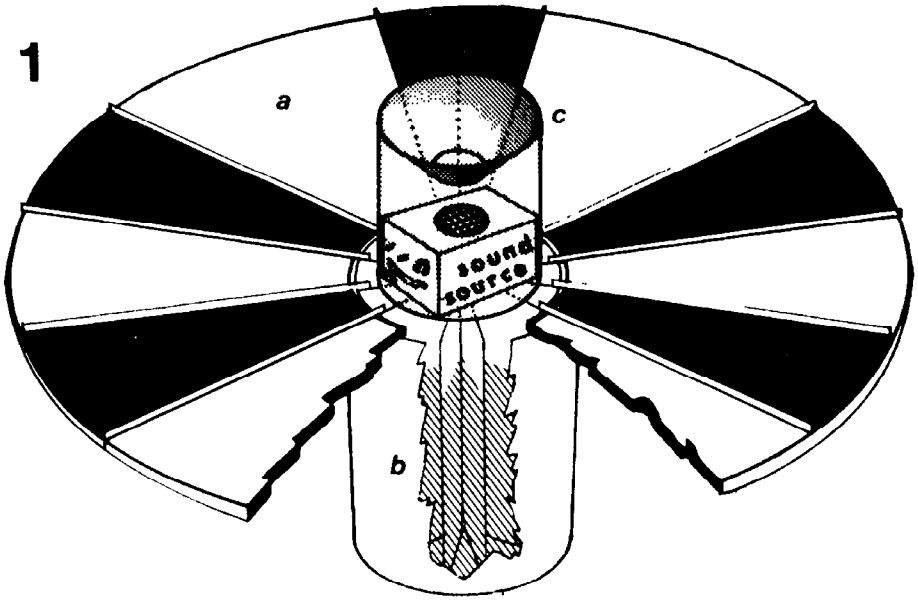

Fig. 1. Experimental device for study of landing orientation in mole crickets attracted to a synthetic calling song. Crickets landing on the horizontal circular wooden board (a) (diameter 1.2m), painted with alternate black and white stripes, were trapped in the partitioned 19-liter bucket (b). Metal bands prevented the insects crossing to a different area after landing and guided them to the corresponding pitfall. Crickets landing on top of the sound source were captured in the cylindrical screen cage.

The attractiveness of the different visual stimuli was measured by the number of insects landing on them. A χ^2 square test was used to compare the observed frequency of landing to an expected frequency based on a radially uniform landing distribution.

Results

Tests for visual orientation at landing.

1. Black stripes against a white background: In this situation (Fig. 2) 6 black stripes, sustaining 20° each, received 40% (348 of 870) of the insects landing on the board. This significan tdeviation from expected (χ^2 = 17.40, P<0.001) could be due to (a) an orientation toward the low reflecting black surface (i.e. "scototaxis"; Alverdes 1930); (b) attraction toward the visual form of stripes standing against a background; (c) attraction toward the edges of the figures (i.e. "perigrammotaxic orientation"; Michieli 1959).

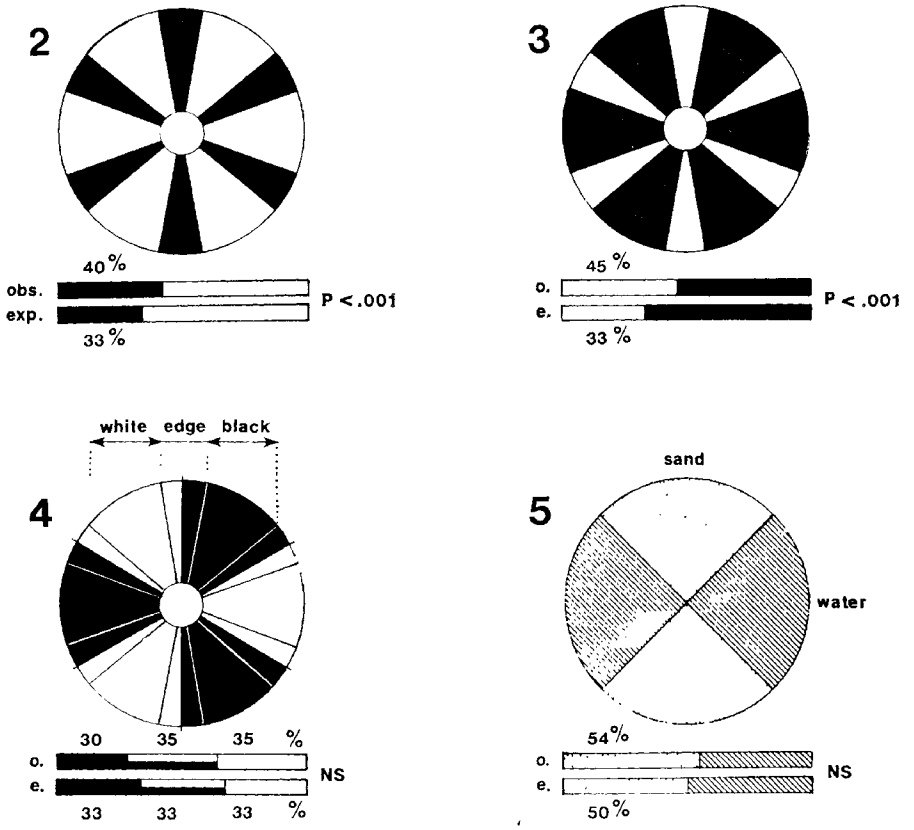

Fig. 2-5. Landing frequencies. 2) With 6 black stripes (covering 6x20°) on white background (6x40°). 3) With 6 white stripes (covering 6x20°) on black background (6x40°). 4) With 3 black and 3 white stripes of same width (covering 6x60°). Orientation to edges was evaluated by trapping mole crickets landing on 6 half black and half white stripes covering 20° each. 5) In a partitioned wading pool (diameter 1.5 m) with 2 liters of sand and 2 liters of water.

To clarify among these assumptions, the following experiments were conducted.

2. White stripes against a black background: In this reversed situation (Fig. 3), 45% of the landings (1134 of 2508) occurred on the white stripes. This significantly greater than expected number of landings ($\chi^2 = 159.34$; $P<0.001$) on the white refutes the role of a scototaxis in the former experiment and reveals the importance of stripes as an attractive stimulus.

3. No form discrimination available: In this control experiment (Fig. 4), 3 black areas alternated with 3 white areas of the same size (60° each). Consequently, no visual form could be distinguished from its background. Edge orientation was estimated by trapping insects landing on the 6 boundaries (20° each) between each black and white area (40° each). Observed landings ($\Sigma = 616$) occurred with similar frequencies on each of the 3 patterns ($\chi^2 = 3.65$; $P>0.05$).

These data show the importance of the stripe/background feature of the visual stimulus in the 2 first experiments. This importance was confirmed in the sand vs. water situation (Fig. 5) where no significant differences in the frequency of landings were observed ($\chi^2 = 0.90$, $P>0.05$). A slight preference for white surfaces appeared in all the experiments: 45% for white stripes against 40% for black ones, Fig. 2, 3; and 35% for white areas against 30% for black ones, Fig. 4.

Tests for the effects of weather conditions on landing.

Temperatures were similar for all experiments: 18.6-22.2°C. The base area of the cylindrical screen cage over the sound source was 2.78% of total landing area. With no wind, a significant number of "excess" landings occurred on top of the sound source (86/2224= 3.87% with $\chi^2 = 9.77$; $P<0.005$). With winds 1.6-4.8 kmph, the number of excess mole crickets that landed in the center was not significant (43/1248 = 3.45% with $\chi^2 = 2.07$; $P>0.05$). With winds >4.8 kmph, no mole crickets landed in the center (0/315; $\chi^2 = 8.99$; $P<0.005$).

Discussion

Landing reactions of some insect species have been studied under laboratory conditions. Expansion of the stimulus in the visual field of the fly (Goodman 1960) or a decrement of the environmental light level (Taddei and Fernandez 1973) elicit the landing responses. These authors define the landing reaction as an all-or-none reaction to a contrasting object that is approached in flight (Fernandez and Taddei 1975). However, for a given insect, attractiveness of a visual pattern may be due to different stimulating characteristics (size, shape, brightness, contrast, etc.). In bright light conditions, a photonegative wood cricket, *Nemobius sylvestris*, orients toward a black stripe against a white background by scototaxis (Campan and Medioni 1963). When in the same experimental conditions, a photopositive wingless insect, *Lepismachilis targionii*, orients toward the black stripe mainly by perigrammotaxis (Goulet et al. 1976). These studies show that determinants in visual orientation are relative to overall experimental conditions. In dim illumination, as at night, the optimum signal characteristic is white reflectance (Hailman 1977). Observed percentage of landings in *S.*

acletus are greater on white areas than on black areas. This could also be due at night to UV radiations mainly provided by the skylight and reflected by white surfaces (Mazokhin-Porshnyakov 1969). Observations of mole crickets landing on stripes show that they were able to distinguish this optical signal from its background. They landed significantly more often ($P<0.001$) on stripes placed on a contrasting background, whatever the sign of the contrast (black/white or W/B), without showing any preferences to the periphery. Study of landing on top of the sound source shows the negative influence of wind conditions on the accuracy of the landing. Even if the wind allows perception of the sound source at a greater distance, it may affect flying insects by increasing energy costs of upstream flights toward the sound source and by decreasing the ability of an accurate landing on top of the singer's burrow.

These results clearly demonstrate that, during landing, *S. acletus* can display an orientation involving form vision discrimination, and this suggests a need for further visual orientation studies in this and other species.

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A LEAF MINER (DIPTERA: EPHYDRIDAE) AND ITS PARASITOIDS ON *SPARTINA ALTERNIFLORA* IN NORTHWEST FLORIDA

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ABSTRACT

The shore fly, *Hydrellia valida* Loew (Diptera: Ephydridae), commonly mines the leaves of salt marsh cord grass, *Spartina alterniflora* Loisel, at Oyster Bay, northwest Florida. Its larvae are frequently parasitized by *Opius* sp. (Hymenoptera: Braconidae), and sometimes by *Pteromalus* sp. (Hymenoptera: Pteromalidae) and *Sympiesis* sp. (Hymenoptera: Eulophidae).

RESUMEN

La mosca de la costa, *Hydrellia valida* Loew (Diptera: Ephydridae), mina frecuentemente las hojas de *Spartina alterniflora*, hierba de la cienaga salada, en Oyster Bay, Florida noroeste. Sus larvas son parasitadas frecuentemente por *Opius* sp. (Hymenoptera: Braconidae), y a veces por *Pteromalus* sp. (Hymenoptera: Pteromalidae) y *Sympiesis* sp. (Hymenoptera: Eulophidae).

The shore flies constitute a medium sized family of acalyptrate Diptera. They exhibit several different modes of life, mostly in aquatic habitats. *Hydrellia* Robineau-Desvoidy and *Lemnaphila cresson* are the only known genera of leafmining ephydrids (Deonier 1971). This is the first record of an ephydrid attacking *Spartina alterniflora* Loisel in Florida. *Hydrellia valida* Loew was the only leafminer reared from this host in our intensive studies of the arthropods of *S. alterniflora* in Oyster Bay, Wakulla County, northwest Florida.

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Life History

Eggs appear similar to those depicted for *Hydrellia griseola* (Fallén) (Grigarick 1959). They are pale white, cylindrical, elongate and about 0.15 x 0.6 mm. The chorion is sculptured with delicate irregular longitudinal ridges. Eggs are deposited longitudinally between or on the leaf ribs of the adaxial surface of the leaf. They are generally laid towards the axil and central part of the blade of the younger leaves of a stem (Table 1). Although Grigarick (1959) observed up to 52 eggs of *H. griseola* per rice blade, we found a maximum of 17 eggs per *Spartina* leaf, with a mean of 4.9 ± 4.0 S.D.

Larvae are white and may reach 4 mm in length. They create straight, narrow mines (Fig. 1). This is common behavior for *Hydrellia* larvae mining grasses (Deonier 1971) in contrast to the tortuous and blotch-like mines of larvae feeding in broad leaves. Of 111 larvae, 85% were found mining towards the leaf apex. The upper epidermal layer of the mine rises, similar to a blister, and the bulge of the larva is easily observed or felt if the leaf is slid between the fingers. The mean number of larvae per leaf was 1.68, maximum 4. This is considerably less than the number of eggs per leaf, indicating substantial mortality in either the egg or early larval stages. Mortality could derive from natural enemies, parasitism, competition between larvae, or from other sources. However, different mines often merged with no apparent adverse competitive effect on larvae, and several larvae were found inhabiting the same mine.

Puparia (Fig. 2) are between 3.5 and 4 mm long, pale brown when healthy or dark brown when parasitized. The pupal period ranged from 7 to 9 days, with an average of 8.05 (n=18). The maximum number of puparia observed per leaf was 4, mean 1.4. Three to 5 puparia per leaf is not uncommon for this genus (Grigarick 1959). Puparia were often located within the older or more basal leaves of a stem (Table 1). As in most leaf-mining ephydrids, pupation occurs within the mine. This behavior is distinctly adaptive on *S. alterniflora*, an intertidal host that can be twice daily innundated by the sea (McCoy and Rey unpublished). Larvae pupating on the ground could easily could be drowned or washed away. Adult flies emerge through the operculum of the puparium. The operculum initially remains attached posteriorly because the ecdysis cleaveage line extends only around the front and side (Deonier 1971).

Life Cycle

Hydrellia valida is multivoltine with several sequential generations dur-

TABLE 1. Location of life stages of *Hydrellia valida* on leaves of *Spartina alterniflora*, 11 May 1980.

Stage	Leaf no., from base to apex				
	1	2	3	4	5
Egg	1	23	65	29	0
Larva	49	109	44	4	0
Puparium	81	64	11	0	2

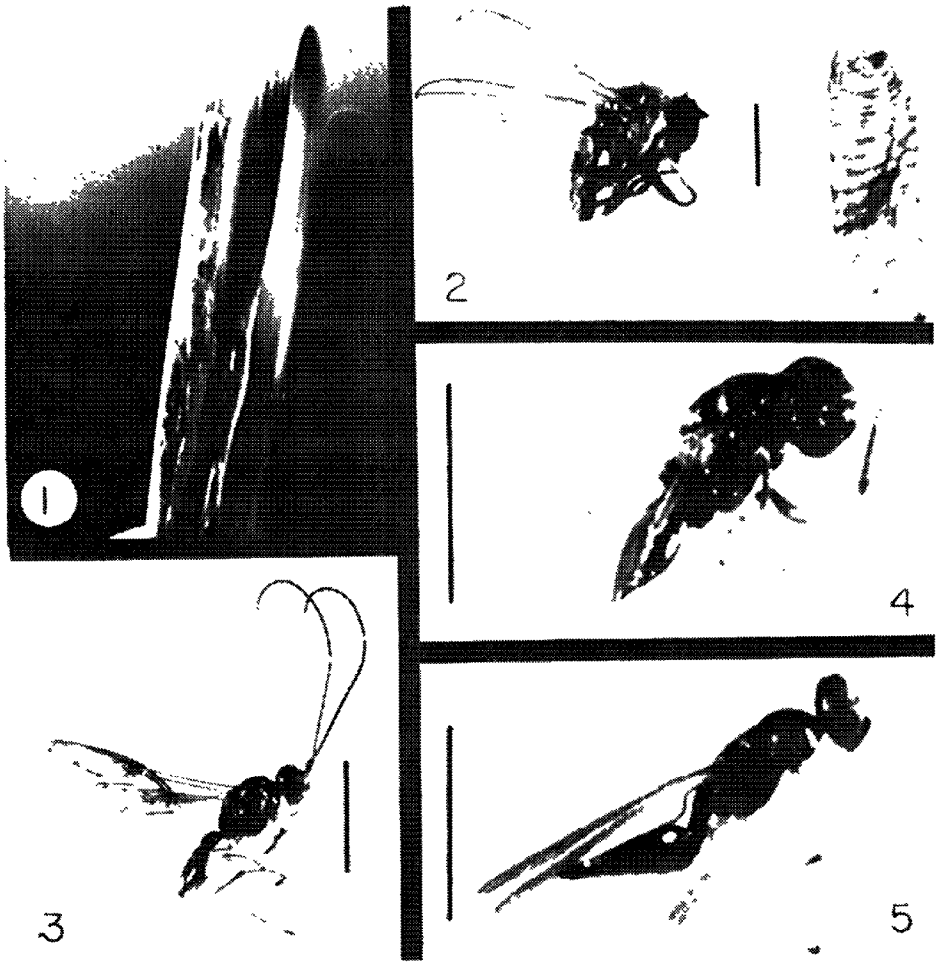

Fig. 1-5. 1) Typical mine. 2) *Hydrelia valida* and puparium. 3) *Opius* sp. (Hymenoptera: Braconidae). 4) *Pteromalus* sp. (Hymenoptera: Pteromalidae). 5) *Sympiesis* sp. (Hymenoptera: Eulophidae). Scale lines are **1 mm.**

ing spring and early summer. At Oyster Bay, Florida, mines first appear in mid April, peak in May, and have usually disappeared by the end of June (Table 2). Mines are generally concentrated in the most shoreward plants, where over 90% of the plants and 65% of their leaves may be mined. Many members of the genus *Hydrellia* are polyphagous (Deonier 1971) and *H. valida* may overwinter either as larvae on other hosts that grow further inland, or as adults.

Parasites

Of 187 insects reared from *Hydrellia* larvae or puparia in 1980, 88.3% were parasites. Parasitism by *Opius* sp. (Hymenoptera: Braconidae) (Fig. 3) was 78.1%; by *Pteromalus* sp. (Hymenoptera: Pteromalidae) (Fig. 4) 9.1%; and by *Sympiesis* sp. (Hymenoptera: Eulophidae) (Fig. 5) 1.1%.

TABLE 2. TEMPORAL VARIATION IN ABUNDANCE AND PARASITISM RATES OF *Hydrellia valida* ON SHORELINE *Spartina alterniflora* AT BOGGY ISLAND, OYSTER BAY, NORTHWEST FLORIDA, 1980.

Date (day, month)	No. per 20 plants		% Parasitism
	Larvae	Pupae	
27-IV	14	4	59.5
18-V	45	32	75.0
2-VI	10	12	94.1
9-VI	23	12	95.0
30-VI	3	1	100.0

Braconids commonly exert the greatest degree of parasitism on *Hydrellia* (Grigarick 1959). *Sympiesis* sp. are believed to be external larval feeders because they pupate free of their host. For *Opius* sp. and *Pteromalus* sp., only 1 parasite was seen to occupy and emerge from each host puparium. At emergence, these parasites cut their own exit holes rather than use the host's puparial operculum. Parasitism by all species was first seen during the host's larval stages. Throughout most of the spring, parasitism was about 90%, after a sharp increase in April and early May (Table 2). Grigarick (1959) reports a similar seasonal increase in parasitism of *H. griseola*, from less than 50% in April to nearly 90% in July.

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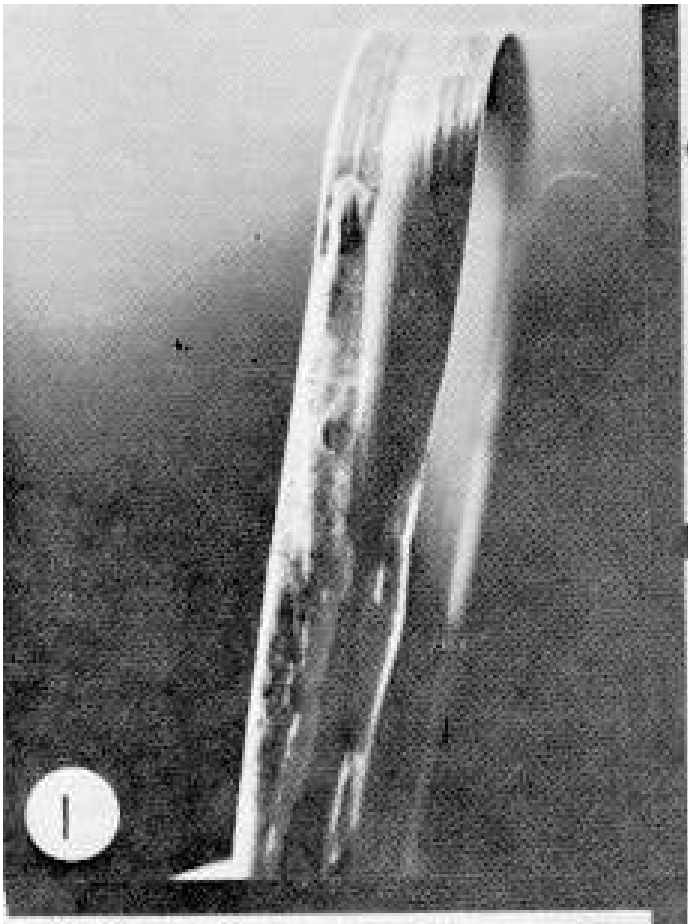
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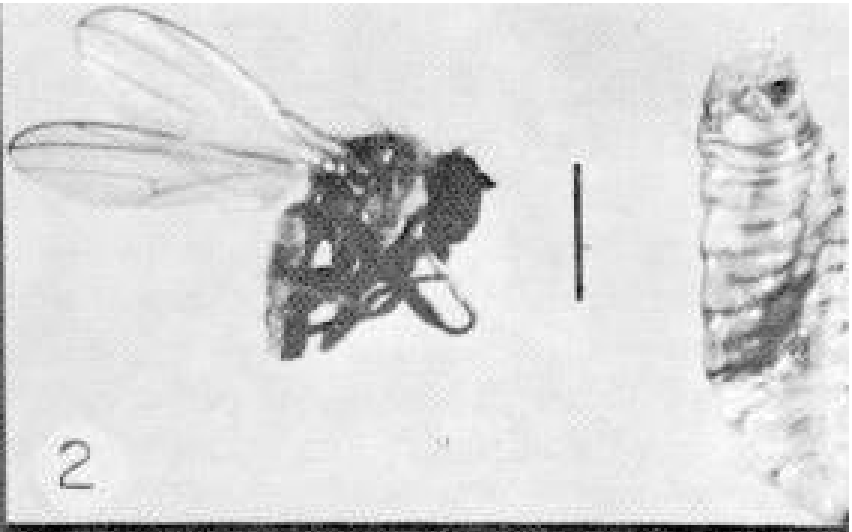
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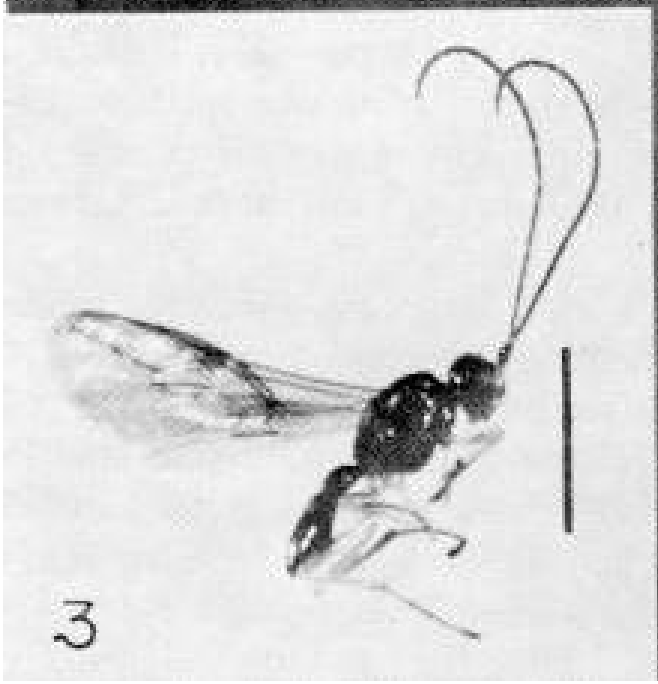
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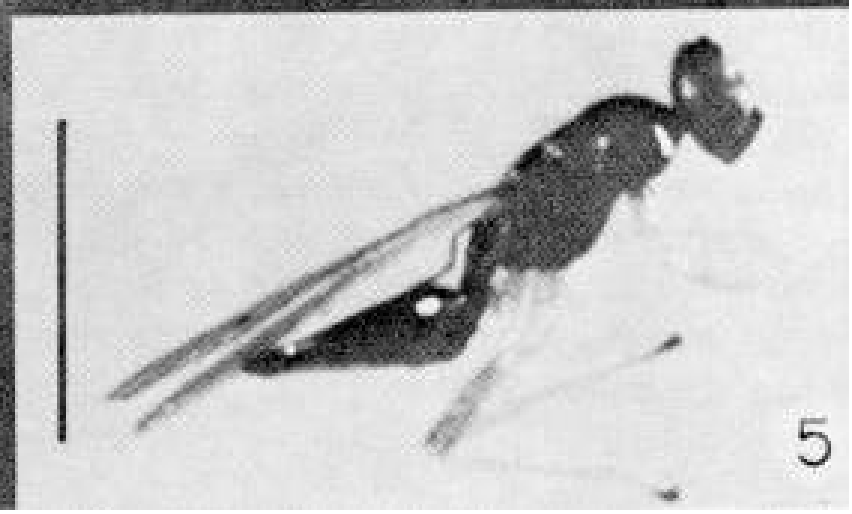
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ELI LILLY EL-468, A NEW BAIT TOXICANT FOR CONTROL OF THE RED IMPORTED FIRE ANT[1,2]

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ABSTRACT

Eli Lilly EL-468, a phenylenediamine, possesses the delayed-toxicity necessary for a bait toxicant to control colonies of the red imported fire ant, *Solenopsis invicta* Buren. In laboratory tests it gave delayed action over more than a 10-fold range of concentrations; in field tests, baits formulated on pregel defatted corn grits and applied at 20 and 40 g AI/ha produced as high as 86 and 91% control.

RESUMEN

Eli Lilly EL-468, una fenilenodiamina, tiene la toxicidad retardada que se nesecita para poder usarlo con cebos para controlar las colonias de la hormiga roja importada, *Solenopsis invicta* Buren. En pruebas de laboratorio se mostró actividad retardada en un rango de concentraciones de 10 incrementos. En pruebas de campo, se obtiuvieron control de hasta 86 y 91% con cebos formulados con maíz a medio moler con la manteca extraida y la condición "pre-gelatinosa" que fue aplicada a 20 y 40 g IA/ha.

Large-scale control programs for the red imported fire ant (RIFA), *Solenopsis invicta* Buren, were conducted with mirex baits from the early 1960's through 1977 (Lofgren et al. 1963, 1964, Banks et al. 1973, Alley 1973). On 30 June 1978 the registrations of mirex were cancelled by the Environmental Protection Agency. Justification for the action was attributed to (1) the discovery of mirex residues in the environment (Ludke et al. 1971, Mehendale et al. 1972, Baetcke et al. 1972); (2) its toxicity to estuarine organisms (Lowe et al. 1970, 1971); and (3) its carcinogenic properties (Innes et al. 1969, Mrak 1969).

Laboratory and field studies by Williams et al. (1980) and Banks et al. (1981) led to the conditional registration of AC 217,300 (2(1H)-pyrimidinone, tetrahydro-5,5-dimethyl-, [3[4-(trifluoromethyl)phenyl]-1-[2-[4-(trifluoromethyl)phenyl]ethenyl]-2-propenylidene]hydrazone) by the Environmental Protection Agency for the control of RIFA in August, 1980. Presently, this is the only chemical registered for area-wide control of the RIFA.

In an effort to find delayed-action toxicants for use in RIFA baits, USDA (ARS) scientists have evaluated hundreds of chemicals each year, with more than 6,500 chemicals evaluated since 1957. Very few have showed the delayed toxicity required for a bait toxicant (Banks et al. 1977) and only mirex and AC 217,300 were registered for commercial use.

[1]Hymenoptera: Formicidae.
[2]Mention of a pesticide, commercial or proprietary product does not constitute an endorsement or recommendation by the USDA.

Recently a new chemical, EL-468, (N-[2-amino-3-nitro-5-(trifluoromethyl) phenyl]-2,2,3,3-tetrafluoropropanamide) produced by Eli-Lilly and Company has shown promise in our laboratory and field studies. In this paper we report the results of these tests.

Materials and Methods

Laboratory evaluation procedures for bait toxicants were described by Williams et al. (1980). Chemicals are first evaluated against worker ants in a primary screening test. Those chemicals showing delayed toxicity (defined as <15% kill at 1 day but >89% after 14 days) are given secondary screening tests against whole laboratory colonies containing a queen and workers in all developmental stages. The chemicals that cause >90% mortality in addition to killing or sterilizing the colony queen are selected for small-scale field tests to prove efficacy against natural populations of RIFA.

A brief description of the primary screening test is as follows. Twenty worker ants from laboratory colonies that had been without food for 14 days were placed in 30 ml disposable plastic medicine cups ca. 24 hrs preceding the test. Candidate chemicals were dissolved directly in once-refined soybean oil (SBO) and offered to the ants on cotton swabs placed in small vial caps. The ants were allowed to feed on the treated SBO for 24 hrs, then the swabs and vial caps were removed from the cups and the ants remained without food for an additional 24 hrs. New vial caps containing cotton swabs saturated with untreated fresh SBO were placed in the cups and left for the remainder of the test period. Knockdown and mortality counts were made at intervals of 1, 2, 3, 6, 8, 10, and 14 days following initial exposure. Each test consisted of 3 replications at 3 concentrations, 1.0, 0.1, and 0.01%.

The secondary screening tests were as follows. The chemicals were dissolved at 1.0, 2.5, and 5.0% by weight in once-refined SBO and then impregnated on pregel defatted corn grits (Lauhoff Grain Company, Danville, Illinois) at 30% by weight of total formulation. Five grams of the formulated bait were placed in disposable plastic weighing boats (100 ml cap.) and then each boat was placed in a laboratory colony starved for 5 days prior to the test. The ants were allowed to feed on the bait for 96 hrs, then the bait was removed and replaced with the standard laboratory diet of honey-water (1:1) and Bank's diet (Williams et al. 1980). General observations on the condition of the colony and mortality counts (estimation of dead ants and brood) were recorded weekly. The tests were continued until the queen, brood, and >90% of the workers were dead (in the case of the queen, complete sterility was sufficient) or the colony had recovered and returned to a normal condition. This condition was considered reached after the queen resumed egg laying and all stages of immatures were present. Each concentration was tested against 2 laboratory colonies consisting of 60 to 120 thousand workers and 50 to 60 ml of brood.

The field tests were conducted in Hamilton County, Florida. The chemical was dissolved at 2.5 and 5.0% by weight in once-refined SBO. Pregel defatted corn grits were impregnated with the oil solution at 30% by weight of total formulation to yield baits containing 0.75 to 1.5% active ingredient. The baits were applied with a tractor-mounted auger applicator (Williams et al. unpublished data) at 20 and 40g AI/ha (8.4 and 16.5 g AI/A). Amdro®, which is a formulated bait of AC 217,300 from American Cy-

anamid Company, Princeton, New Jersey, was applied as a standard at 10 g AI/ha (4.3 g AI/A) for comparison. All treatments were conducted on 0.4 ha plots (3 replications per treatment) located in non-grazed permanent pasture. Controls were 3 untreated plots (0.4 ha each).

Pre- and post-treatment counts of the number of active nests, the size of the nests, and the presence (normal) or absence (abnormal) of worker brood were recorded from 0.2 ha (0.5 acre) circles within each treatment block.

The percentage control in the field tests was determined by making post-treatment evaluations at 6, 12, and 21 wk intervals using the method described by Harlan et al. (1981). This method uses a 10-point system to rate each colony based on the absence (categories 1-5) or presence (categories 6-10) of worker brood. A normal colony of RIFA should contain worker brood, particularly during the warmer months of the year, thus a colony without worker brood would indicate the absence of a queen or the presence of a sterile queen. Also, each colony was rated on its size (no. of worker ants) ranging from <100 workers (categories 1 and 6) to >50,000 (categories 5 and 10). Therefore, categories 1 and 6 (<100), 2 and 7 (100-1000), 3 and 8 (1000-10000) 4 and 9 (10000-50000) and 5 and 10 (>50000) are all the same size but differ in whether worker brood is present or absent. The number of each category in a plot multiplied by the total number of colonies recorded for that category yields the "population index" for each plot. The difference between the pre- and post-treatment population indexes was used to calculate the percentage control for each treatment.

Results and Discussion

In the laboratory primary screening tests EL-468 exhibited delayed toxicity at the 0.1 and 1.0% concentrations (Table 1), but it did not show toxicity at the 0.01% concentration. In comparison, mirex gave delayed kill at all 3 concentrations. When tested in a bait against entire laboratory colonies (Table 2) EL-468 killed 95 to 100% of the individual ants within each colony in 1 wk and all colonies were dead after 8 wks.

The results of field tests (Table 3) suggest that EL-468 gave better control with both concentrations than the standard, Amdro®, at 6 wks and as good as or slightly better control at 12 wks; however, the differences were

TABLE 1. Results of primary screening tests with Eli-Lilly EL-468 against red imported fire ants (Avg. of 6 tests).

Treatment	Conc. (%) in SBO	Percent knockdown and mortality after indicated number of days						
		1	2	3	6	8	10	14
EL-468	0.01	1	1	1	1	4	8	18
	0.1	0	4	12	55	79	89	97
	1.0	4	33	78	100			
Mirex standard	0.01	0	1	1	7	39	84	98
	0.1	1	2	17	66	84	92	100
	1.0	0	57	90	100			
Soybean oil check	—	0	0	0	1	2	4	7

TABLE 2. EFFECT OF CONCENTRATION OF EL-468 AGAINST LAB COLONIES OF RIFA (5 GMS BAIT/COLONY); 30% SBO ON PREGEL DEFATTED CORN GRITS; 1 COLONY/TREATMENT.

Conc. (%) in SBO	Percent knockdown and mortality after indicated wks*				
	1	2	3	4	8
1.0	95	97	98	99	D
1.0	99	D			
2.5	99	99	99	D	
2.5	99	D			
5.0	D				
5.0	D				
5.0 (AC 217,300)**	99	D			
Check	0	0	0	1	5

*D = death of colony.
**AC 217,300 (Amdro) was used as the standard.

not statistically significant. Evaluations for 21 wks post-treatment showed no significant differences but it appeared that the low concentration of EL-468 was not as effective as the standard or the higher concentration of EL-468. EL-468 was applied at 2X and 4X the rate of AC 217,300 in the standard (Amdro®) in these field tests, because a preliminary study indicated an equivalent (1X) rate per hectare gave a maximum of 60% control. However, more recent tests in Mississippi (Banks et al. unpublished data) have shown good control of RIFA with rates as low as 3.2 g/ha. Also, Williams et al. (1980) reported laboratory screening data for AC 217,300 that suggests that at the equivalent concentrations, the 2 compounds are equally toxic. It is possible that the apparent variations in results reflect formulation differences which will be resolved in subsequent studies under an Environmental Use Permit.

An obvious difference between EL-468 and AC 217,300 is that the former does not exhibit the specific effects on the colony queen that were noted with

TABLE 3. CONTROL OF RED IMPORTED FIRE ANTS WITH EL-468 IN FIELD TESTS IN HAMILTON COUNTY, FLORIDA. EACH TREATMENT APPLIED TO 3 1-ACRE PLOTS.

Chemical	Conc. (%) in oil*	Application rate		Percent control after indicated wks**		
		kg/ha	g AI/ha	6	12	21
EL-468	2.5	2.8	20	75a	86a	72a
EL-468	5.0	2.8	40	77a	91a	86a
AC-217,300 (Standard)	2.5	1.4	10	66a	88a	80a
Untreated control				7b	11b	9b

*30% Soybean oil on pregel defatted corn grits.
**Avg. 3 replications. Means in the same column not followed by the same letter are significantly different at the 5% level of confidence based on Duncan's multiple range test.

the latter compound (Williams et al. 1980). Despite these facts, our data show that EL-468 is an effective delayed-action toxicant which could be an additional useful tool for the control of imported fire ants and possibly other pest ant species.

EL-468 can be referred to chemically as a phenylenediamine and thus it represents the second new class of chemicals that we have discovered that exhibit delayed toxicity.

ACKNOWLEDGEMENTS

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DEVELOPMENTAL RATES AND EMERGENCE OF VEGETABLE LEAFMINER[1] PUPAE AND THEIR PARASITES REARED FROM CELERY FOLIAGE[2]

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ABSTRACT

Vegetable leafminers, *Liriomyza sativae* Blanchard, were reared from '2-14' celery foliage held at different constant temperatures to determine the influence of temperature on pupal development and on host and parasite emergence. Significantly ($P \leq 0.05$) greater numbers of leafminer pupae were obtained from celery leaflets held at 32.2°C than at 15.6°C. The percent emergence of adult leafminers was significantly greater ($P \leq 0.05$) at the higher rearing temperature (75% emergence above 20°C and 45% emergence below 20°C). Larval parasite emergence (*Diglyphus intermedius* (Grit.) and *Chrysonotomyia formosa* (Westwood)) was significantly ($P \leq 0.05$) greater at temperatures below 23°C (43%) than at higher temperatures (29%). Leafminer pupal developmental time under constant rearing temperatures increased from 5-7 days at 32.2°C to 21.0 days at 15.6°C.

Pupal development required a mean 127.8 degree-days, with an estimated lower threshold temperature of 10.0°C. The degree-day requirements for pupal development were not significantly different at constant rearing temperatures of 15-35°C.

RESUMEN

Los minadores de hojas de vegetales, *Liriomyza sativae* Blanchard fueron criados en el follaje de apios '2-14' mantenidos a distintas temperaturas constantes para determinar la influencia de la temperatura sobre el desarrollo pupal y el surgimiento del huésped y el parásito. Un número significativamente mayor ($P \leq 0.05$) de pupas de minadores de hojas fueron obtenidos en ojitas de apio mantenidas a 32.2°C que de las mantenidas a 15.6°C. El porcentaje de produccion de adultos de los minadores fué significativamente mayor ($P \leq 0.05$) a temperaturas de cría más altas (75% a más de 20°C, y 45% bajo 20°C). El surgimiento de parásitos larvales (*Diglyphus inter-*

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medius (Grit.) y *Chrysonotomyia formosa* (Westwood)) fué significativamente mayor ($P \leq 0.05$) a temperaturas bajo 23°C (43%) que a temperaturas más altas (29%). El tiempo de desarrollo de pupas de mina doras de hojas bajo temperaturas de cría constantes subieron de 5-7 días a 32.2°C, a 21.0 días a 15.6°C

El desarrollo pupal tomó un promedio de 127.8 días de grados, con un mínimo de temperatura estimado a 10.0°C. El requerimiento del desarrollo pupal no fué significativamente distinto a temperaturas constantes de 15-35°C.

Only general information is available concerning the biology of serpentine leafminers, *Liriomyza* (Diptera: Agromyzidae) and their parasites, largely because of the difficulty in identifying the leafminer species. Several temperature regimes are used in this study to provide data to calculate developmental rate, percent emergence and estimation of degree-days for the leafminer pupae, *Liriomyza sativae* Blanchard, and its parasite, *Opius* spp. Information about the influence of temperature on the biology of the leafminer is essential for explaining leafminer population dynamics. Such data may explain not only fluctuations in field populations but help evaluate the influence of laboratory rearing environments on samples used to estimate population density.

The rate of insect development often approximates a linear function of temperature and this relationship is the basis for computing accumulations (Abrami 1972). The theory of temperature summation defines an index for heat energy required to complete a given stage of development (Eckenrode and Chapman 1972). Degree-days, or heat units, have been useful methods in predicting developmental times for insects (Williams and MacKay 1970, Reid and Laing 1976). Allen (1976) provides a modified sine wave method for calculating degree-days and modifications for local geographical biases. In Florida, nocturnal temperatures are relatively constant, thus the sine wave model tends to over-estimate degree-day values.

Materials and Methods

Vegetable leafminers were obtained from leaflet samples collected from commercial fields of '2-14' celery in May 1978 at Belle Glade, Florida. These samples were placed in 165 pint-size paper sherbet containers each with 12 trifoliolate celery leaflets and were taken to the laboratory at the University of Florida, Gainesville. Fifteen containers were placed at each of 11 temperature regimes in growth chambers. Eight samples were held at constant temperature of 32.2°, 29.4°, 26.7°, 23.9°, 22.2°, 21.1°, 18.2°, or 15.6°C ($\pm 3°$ each). Two other samples were exposed to fluctuating temperatures. One regime simulated Orlando, Florida during January 1978 and was based on historical data from U.S. Weather Bureau statistics with an average daily high and low temperature of 16°C and 2°C, respectively, and with 7 nights of subfreezing temperatures (—0.5 to —4.0°C). The other regime, a 16°C day and 2°C night temperature cycle (12 h each temperature) eliminated the influence of freezing on leafminer emergence and development. The average R.H. in each of the growth chambers was 54%. The 11th regime was in an outdoor rearing cage in Gainesville, Florida, during June 1978. The average daily high and low temperatures in this cage were 32.4°C

and 21.9°C, respectively with R.H. ranging from 74% to 99% (average was 89%).

All newly formed leafminer pupae were removed daily from the rearing containers, placed in separate 4 oz. plastic vials, and were held at the same temperature regime from which the pupae were collected. Each day both containers and vials were observed and emerged leafminer adults and their parasites were removed, identified and counted. Degree-day values were determined for each experimental temperature trial using Allen's (1976) Fortran program. Development rates (1/time) were calculated for each of the 8 constant temperatures.

Results and Discussion

Temperature was a significant factor influencing the mean number of leafminer pupae collected per celery leaf (Table 1). The leafminer pupae parasitized by the pupal parasite, *Opius* spp., were not identified and separated until adults of both insects had emerged. Percent emergence of adults from leafminer pupae (leafminer and *Opius* spp.) was greater at constant temperatures above 21.1°C (75% emergence). Of the total adults (leafminer and *Opius* spp.) emerging from leafminer pupae, leafminer adults formed 94% of the emerging adult population. The fluctuating Gainesville regime resulted in 62% emergence. This lower value was attributed to decay of foliage in rearing containers and vials. The Orlando regime with 7 nights of subfreezing temperatures reduced adult emergence to 13.9%. At the

TABLE 1. Emergence of adult vegetable leafminer, *Liriomyza sativae* Blanchard, and its parasites from '2-14' celery foliage held at 11 temperature regimes.

Rearing temperature regimes (C°)	Mean number leafminer pupae/ trifoliolate	% Adult[1] emergence from pupae	% Adult parasite[2] emergence from pupae	% Total[3] parasitism
32.2	7.2a[7]	84.7a	6.9ab	28.2b
29.4	6.1ab	86.8a	4.6ab	22.8b
26.7	5.6b	88.9a	5.5ab	23.4b
23.9	5.4b	77.4a	3.5b	18.5b
22.2	5.6b	78.3a	5.0ab	43.7a
21.1	5.3b	78.5a	6.2ab	49.5a
18.2	5.2b	47.1b	8.2ab	53.7a
15.6	3.4c	43.7b	11.7a	54.3a
Orlando[4]	0.7–	13.9–	2.3–	51.5–
Gainesville[5]	12.6–	62.1–	9.7–	21.9–
16.2[6]	1.8–	43.2–	17.7–	70.1–

[1]Leafminer and *Opius* spp. adults.
[2]*Opius* spp. only.
[3]Includes *Opius* spp., *Chrysonotomyia formosa* and *Diglyphus intermedius*.
[4]Regime simulated daily Orlando, Florida high and low temperatures during 4-30 January 1978.
[5]Reared in protected cages outdoors in Gainesville, Florida during 1-19 June 1978.
[6]12h:12h temperature cycle of 16°C day and 2°C night.
[7]Means followed by the same letter in each column are not significantly different according to Duncan's multiple range test ($P \leq 0.05$). Means without letters were not included in the analysis.

cooler temperatures the number of *Opius* spp. adults emerging from leafminer pupae was significantly greater ($P<0.05$) than the adult leafminer emergence. Under 16°:2°C temperature regime there was significantly ($P<0.05$) more *Opius* spp. parasitization (17.7%) than under the Orlando regime (2.3%). This suggests that cool and freezing temperatures affected survival of the parasite or of the parasitized host.

Total parasitism included *Opius* spp. (3.2%), and the 2 larval parasites *Chrysonotomyia formosa* (Westwood) (74.4%) and *Diglyphus intermedius* (Girault) (22.4%). These latter 2 parasites kill leafminer larvae and emerge as adults directly from celery foliage. The proportion of total parasites significantly ($P<0.05$) increased as rearing temperatures decreased and ranged from 18-28% parasitization above 23.9°C and 43-70% at temperatures below 23.9°C. *Chrysonotomyia formosa* was the most numerous of the 3 species of parasites reared. Both *C. formosa* and *Opius* spp. had greater emergence than the leafminer at cooler temperatures. The freezing temperatures of the Orlando regime increased preadult mortality of *Opius* spp. parasities (in vials). Under field conditions leafminer pupae parasitized by *Opius* spp. would be insulated by a layer of soil. This may protect the parasitized pupae from subfreezing (—4°C) temperatures. Previously, Harding (1965) observed a high rate of parasitization and an associated decrease in numbers of miners during the colder months in Texas.

Developmental times for leafminer and *Opius* spp. increased significantly as temperatures decreased (Table 2). Developmental times for leafminer pupae ranged from 5.7 days at 32.2°C to 21.9 days at 15.6°C. In the same temperature range, *Opius* spp. emergence ranged from 6.4 days to 27.4 days. In all trials this parasite required a longer average time (1 day) to mature than did the leafminer.

The longer developmental times for *Opius* spp. relative to the leafminer may provide it a competive advantage over other leafminer parasites when the life cycle of the leafminer and parasite population are synchronized. *Opius* spp. females preferentially parasitize 1st instar leafminers (Lema and Poe 1979). A slight delay in adult parasite emergence would result in an increase in available leafminer larvae. The stages in the life cycle of leafminer field populations are generally synchronized only during initial periods of invasion.

Emergence of adult leafminers and parasites occurred during a longer period of peak emergence (70%) of time at cooler temperatures (7-9 days when reared at 32.2°C, 10-16 days at 23.9°C, 19-39 days at 15.6°C and 21-53 days at the 16°C:2°C temperature regimes). Emergence of adult *Opius* spp. did not demonstrate such a large increase in the number of days to peak emergence (70%) (9-10 days at 32.2°C, 13-14 days at 23.9°C, and 31-36 days at 15.6°C). Five percent of the total adult *C. formosa* and *D. intermedius* emerged 7 weeks or later after collection when reared at the cooler Orlando or 16°:2°C temperature regimes. *Chrysonotomyia formosa* was predominant (97.9% of total adult insects) among late emerging parasites. Leafminer adults at lower temperatures rarely emerged 30 days after collecting the leaf samples (0.8%). The cooler temperatures of the winter months in central Florida permit leafminer and parasite population survival by significantly extending the length of time for their pupal maturation.

TABLE 2. MEAN DEVELOPMENTAL RATE AND DEGREE-DAY VALUES FOR VECETABLE LEAFMINER, *Liriomyza sativae* BLANCHARD, PUPAE AND PARASITE, *Opius* SPP., REARED FROM '2-14' TRIFOLIATE CELERY LEAVES AT 11 TEMPERATURE REGIMES.

Rearing temperature (°C)	*Opius* spp.			*Liriomyza sativae* pupae		
	Developmental time (days)[1]	Degree-days above 10.2°C	Developmental rate (1/day)	Developmental time (days)	Degree-days above 9.6°C	Developmental rate (1/day)
32.2	6.4de[5]	143.6b	0.15	5.7de	128.0a	0.17
29.4	6.8de	134.7b	0.14	6.4de	127.0a	0.15
26.7	8.1d	138.4b	0.12	7.3d	125.3a	0.13
23.9	9.8cd	141.9b	0.10	9.4cd	136.4a	0.10
22.2	10.8c	140.1b	0.09	10.1c	127.0a	0.10
21.1	10.8c	124.6b	0.09	10.3c	118.7a	0.09
18.2	20.0b	173.8a	0.05	15.4b	134.0a	0.06
15.6	27.4a	164.5a	0.03	21.0a	126.3a	0.04
Orlando[2]	12.1–	53.8–	—	10.1–	83.4–	—
Gainesville[3]	9.3–	150.4–	—	8.4–	134.5–	—
16.2[4]	25.3–	51.9–	—	20.7–	42.4–	—

[1]Average time for *Opius* spp. adults to emerge from leafminer papae after leafminer pupation.
[2]Temperature simulated Orlando, Florida during 4-30 January 1978 in growth chamber. Mean temperature 16°:2°C (day/night), 7 nights of freezing (—4°C coldest).
[3]Protected outdoor cages in Gainesville, Florida, 1-19 June 1978. 33.7°/22.4°C day/night average (R.H. 62-99%).
[4]Growth chambers 12hL:12hD—16°:2°C cycle.
[5]Means followed by the same letter in each column as not significantly different according to Duncan's multiple range test (P=0.05).

The growth curve for the leafminer was calculated using % development/day from degree-day values (Fig. 1). Degree-day calculations require a low temperature threshold for pupal development and 10.0°C used. This low threshold temperature for development of leafminer pupae appeared realistic when substantiated by Jensen and Koehler (1970) who found 24% emergence of adult *Liriomyza* sp. at 12.8°C, by data available on other Diptera (Allen 1978, pers. commun.), by *L. sativae* adult emergence of 54% at 15.6°C (Table 1) and 0% at 8.1°C (pers. obs.).

The average heat unit requirements for 2500 leafminer pupae and 210 *Opius* spp. reared at 8 different constant temperature regimes were 127.8 and 141.2 degree-days' C respectively. These 2 means were not significantly different (P=0.05) from degree-day values for each constant temperature regime. These degree-day values reflect the delay in emergence of *Opius* spp. adults relative to the adult leafminer. The only inconsistent degree-day estimations were with pupae reared at the 16°:2°C and Orlando regimes with degree-day values of less than 100. Apparently subthreshold temperatures (10°) affect critical developmental mechanisms within pupae. There is no indication of diapause.

Degree-day requirements and developmental rates for all stages of

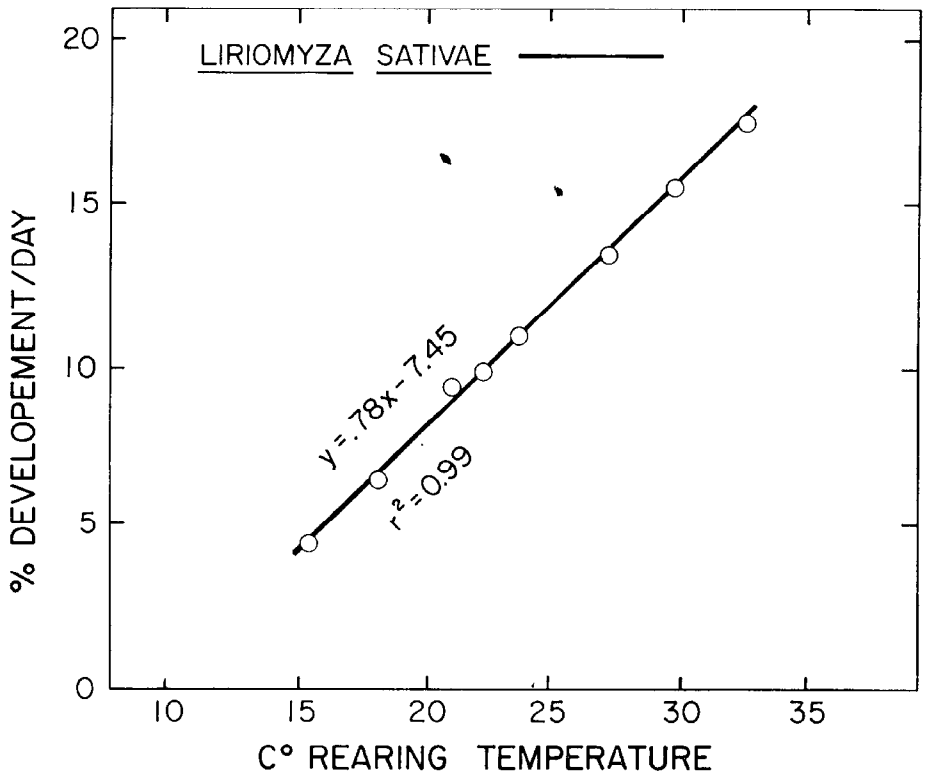

Fig. 1. Influence of constant temperatures on developmental rates of *Liriomyza sativae* Blanchard pupae reared from '2-14' celery foliage (Belle Glade, Fla., Spring 1978, N = 15, 12 trifoliolate leaves per sample; y = developmental rate; x = °C).

Liriomyza will help in predicting population densities vital to developing effective pest management tactics.

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A REVIEW OF *FRANKLINIELLA BRUNERI* WATSON AND DESCRIPTION OF *F. KELLIAE*, N. SP. (THYSANOPTERA: THRIPIDAE)

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Abstract

Frankliniella bruneri Watson, 1925 was rediscovered for the first time in the past 55 years to be a valid species, and is rediagnosed. *Frankliniella pseudotritici* Priesner, 1932 and *inornata* Moulton, 1936 are newly found synonyms. *Frankliniella kelliae*, n. sp., mounted together with the type series of *bruneri*, has otherwise long been confused with another well known species, *F. difficilis*. Both *F. bruneri* and *kelliae* are widely spread and common general flower feeders in the Caribbean area.

Resumen

Frankliniella bruneri Watson, 1925, fue descubierto de nuevo despues de 55 anos como una especie valida, y se diagnostica de nuevo. *Frankliniella pseudotritici* Priesner, 1932 y *F. inornata* Moulton, 1936 son sinónimos nuevos. *Frankliniella kelliae* n. sp. montada junta con la serie típica de *F.*

Liriomyza will help in predicting population densities vital to developing effective pest management tactics.

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bruneri, ha sido confundido por largo tiempo con otra especie bien conocida, *F. difficilis*. *F. bruneri* y *F. kelliae* se alimentan de las flores de diferentes especies y son comunes y distribuidas largamente en la región del Caribe.

Frankliniella bruneri Watson, 1925 from Cuba has remained completely obscure for the past 55 years because of its initial misplacement and insufficient specific description by Watson. Now it is rediscovered to be a valid species and furthermore found to be a widely spread and very common general flower feeder in the western Caribbean area. *Frankliniella pseudotritici* Priesner, 1932 from Mexico and *F. inornata* Moulton, 1936 from Cuba are newly found synonyms of the species. Another *Frankliniella* sp. mounted together with the type series of *bruneri* is another widely spread and very common general flower feeder in the central Caribbean area, and is described here as a new species. The type series of *bruneri* studied is a loan from the Florida State Arthropod Collection (FSAC).

Frankliniella bruneri Watson, REINSTATED, REVISED STATUS (Fig. 1-4)

Frankliniella tritici: Watson 1924:46 (misidentification).
Frankliniella cephalica bruneri Watson, 1926:54; Moulton 1948:91.
Frankliniella cubensis: Jacot-Guillarmod 1974:768, 772 (in part, misidentification).
Frankliniella gemina pseudotritici Priesner, 1932:179, NEW SYNONYMY.
Frankliniella pseudotritici: Jacot-Guillarmod 1974:808.
Frankliniella inornata Moulton, 1936:62; Moulton 1948:63, 94, fig.; Jacot-Guillarmod 1974:782, NEW SYNONYMY.

No second collection of this species has been on record, and no subsequently so determined specimen remains in either USNM or CAS (California Academy of Sciences). Moulton (1948) who had apparently not seen the type series accepted the species as valid, but Jacot-Guillarmod (1974) summarily synonymized with *F. cubensis*, without seeing the type series. This synonymy has no merit.

Type Series: The type series designated for *F. cephalica bruneri* consists of a long series of specimens (30 ♀♀, 4 ♂♂) collected by S. C. Bruner at La Jaula on Peninsula de Duanahacabibes (2 slides) and Santiago de las Vegas (9 slides), Cuba from February to April., 1924 from various hosts: orange, avocado, *Hibiscus rosasinensis*, *Phaseolus helvolus*, *Moringa* sp., and *Rosa* sp. Watson (1924) first determined these as *F. tritici* (Fitch), but 2 years later redetermined them as *F. cephalica bruneri*, n. sp. (1926). The presently remaining type series, which is probably in its entirety, in FSAC is 35 adults and 4 larvae mounted together on 9 slides with Watson's inscription of "type and paratypes" or "paratypes", and 2 other topotypic slides lacking the type status inscription but with same collection data and Watson's writing of *bruneri*, n. sp. All the specimens on these slides are determined as shown in Table 1.

Watson (1926) was deficient in describing the specific diagnostic characters, but then few points mentioned, such as yellowish orange ocellar crescent, dimensions of antennal segments II-IV with diminutive dorsoapical

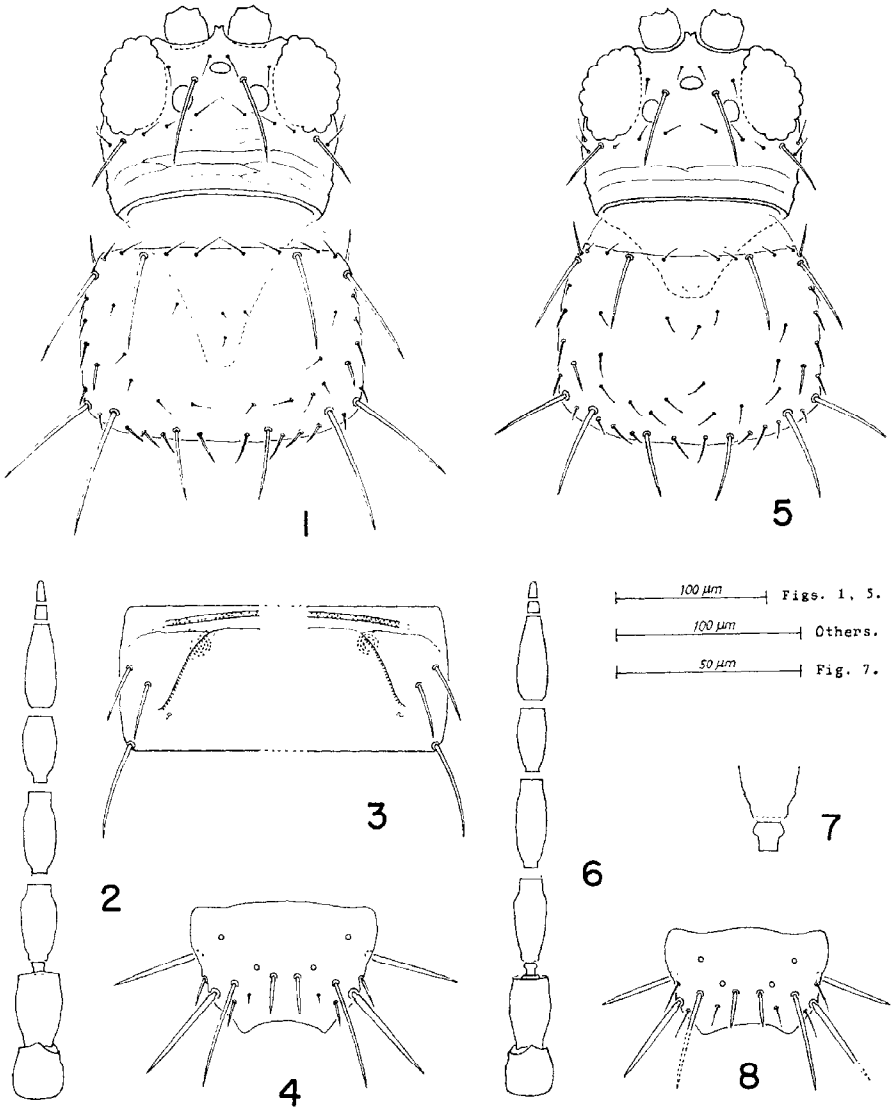

Fig. 1-8. 1-4, *Frankliniella bruneri* (specimens all from Jamaica): 1. Head and prothorax (♀); 2. Antenna, right (♀); 3. Tergite V (♀); 4. Tergite IX (♂). Fig. 5-8, *F. kelliae*: 5. Head and prothorax (paratype ♀); 6. Antenna, left (paratype ♀); 7. Pedicel of antennal III (paratype ♀); 8. Tergite IX (allotype ♂).

production on II and undilated pedicel ("narrow peduncle") of III make Watson's *bruneri* fit only Sp. No. 1 (Table 1). Species No. 1 is also predominating in numbers among all the specimens mounted, and is uniformly represented on every one of the 11 slides, except one that is paired with the other slide of the same collection. Species Nos. 2 and 3 have bright red ocellar cresents, Nos. 2, 3 and 4 all have dilated pedicels, No. 4 has a slender antenna, and No. 5 has a dark body. Watson's placement (1926) of

TABLE 1. SPECIES OF THRIPS MOUNTED TOGETHER WITH THE TYPE SERIES OF *Frankliniella bruneri.*

Species	8 paratype and 2 topotypic slides	A slide with "type and paratypes" inscribed*	Combined
1. *F. bruneri* Watson, 1926	14 ♀♀, 3 ♂♂	3 ♀♀	17 ♀♀, 3 ♂♂
2. *F. cubensis* Hood, 1925	5 ♀♀	1 ♀	6 ♀♀
3. *F. difficilis* Hood, 1925		1 ♂	1 ♂
4. *F. kelliae*, n. sp.	2 ♀♀	1 ♀, 2 ♂♂	3 ♀♀, 2 ♂♂
5. *F. insularis* (Franklin, 1908)	2 ♂♂		2 ♂♂
6. *F. sp.* (damaged)	1 ♀		1 ♀
	22 ♀♀, 5 ♂♂	5 ♀♀, 3 ♂♂	27 ♀♀, 8 ♂♂

*Collection data: La Jaula, orange and avocado, 6-IV-1924, S. C. Bruner.

this species in the *cephalica* group was in error. This error was the primary cause for a long obscurity in which this species had remained until today.

HOLOTYPE: Among the 3 females of *bruneri* on the "type and paratypes" slide, the only one in dorsal mount is selected for the holotype, and a new label is additionally placed. The holotype is redescribed as follows: Color as is described in Diagnosis. Body 1610 (all measurements in micrometers; denotes length only unless otherwise stated; w. = width) (contracted to 950); head about 105, w. 150; interocellar seta 48, postocular seta iv 39. Antenna 268, length (width) of segments: 23(26), 42(24.5) (dorsoapically elevated a little but hardly produced), 53(21) (pedicel undilated), 43(20), 34(18), 45(17), 6.5(6.5), 10.5(5). Pronotum 130, w. 189; setae: anteromarginal 64, anteroangular 62, posteroangular i 82, ii 71, posteromarginal ii 49; pterothorax 200; forewing 750, hind vein with 16 setae; hind tibia 170. Abdomen 1040; comb on tergite VIII indiscernible because of insufficient clearing (see Diagnosis); ovipositor 230; caudal setae: IXi 105, ii 109, iii 115, Xi 112, ii 102.

DIAGNOSIS: A total of 36 ♀♀ and 11 ♂♂ from Cuba, Jamaica and Mexico were measured for this diagnosis. Specimens from Mexico are generally far larger than others. The male form has heretofore not been described. *Intonsa* group—*runneri* complex. *Female*: Yellow body without any gray shading or blotching (see next paragraph); antenna I pale, II grayish brown, basally pale (almost totally pale when teneral), III-V pale yellow, distal 1/3-1/2 of III, 3/4 of IV, 1/4-1/3 of V grayish brown, VI-VIII grayish brown; ocellar crescent brown to reddish brown; wing pale yellow; major setae dark brown to dark grayish brown; integumental sculpture inconspicuous everywhere. Body 1.41-1.86 mm (all distended). Head (Fig. 1) 105-122, broad and rather short (1.4-1.5 times as wide as long); mouth cone fairly long, straight and tapered; interocellar seta about 1/2 as long as head, between anterior and posterior ocelli, postocular seta iv about 2/3 of interocellar seta. Antenna (Fig. 2) 252-303, 2.4-2.6 times as long as head, II somewhat dorsoapically elevated but not produced, III 2.4-2.6 times as long as wide, pedicel simple, style stout (VII+VIII/VII w.: 2.6-2.9). Pronotum (Fig. 1) 1.1-1.2 times as long as head, all major setae subequal, about

1/2 as long as pronotum, posteroangular seta i somewhat longer, posteromarginal seta ii about subequal to interocellar seta, 4 minor setae between anteromarginal setae. Forewing with 14-17 setae on hind vein. Abdomen: ctenidia and chaetotaxy of tergites normal for the genus; comb on tergite VIII complete, teeth medium in length, sometimes shorter at middle, sparse; tergites IX-X with all major setae nearly subequal to each other in length, all longer than tergite X. *Male*: Paler than female, frail, antenna colored as female but II often pale and VI sometimes weakly pale at base. Body 1.01-1.32 mm; head 87-105, about 1.4 times as wide as long; antenna 222-260, 2.5-2.6 times as long as head; sternites III-VII with large subcircular granular area (30-45 μm across); tergite VIII with comb complete but teeth very small; tergite IX (Fig. 4) with 2 pairs of thick major setae on dorsum, outer pair 2.4-3.3 times as long as inner pair; 2 other major setae on side and clasper of sternite in thick and long thorns, sometimes not quite thickened when teneral.

Muscle Marks: Among many specimens examined, some females were seen with an ill-defined, small, circular, faint, brown mark (Fig. 3) near both anterolateral corners of tergites III-VII. These newly discovered marks among *Frankliniella* are not related to ordinary grayish brown blotchings on tergites. These are always in the mesal area along antecosta. According to the interpretation by B. Heming, the muscle marks are localized heavier sclerotization of the cuticle at the origins of some of the lateral abdominal tergo-sternal muscles (Priesner 1926: 60; Hood 1932: 1-6). The muscle marks of this species are usually very faint and discernible only on well cleared specimens, but rarely become fairly conspicuous. The incidence of markings was found persistently among every series from Cuba (but not seen on the type series), Jamaica and Mexico. Similar muscle marks were also found in *F. kelliae* and *difficilis*. (See pages 488 and 490.)

RELATIONSHIPS: *Frankliniella bruneri* is one of the congeners of the *runneri* complex of the *intonsa* group. All congeners are common in possessing a normal head shape, undilated antennal pedicel, and pale to yellow body without any blotching on abdomen. They are all poorly characterized from each other, and diagnostic characters are very limited in most of the cases. A workable key to species is desperately needed. *Frankliniella bruneri*, together with *gossypiana* Hood, belongs to a small group that is characterized by fully developed postocular seta iv, anteromarginal pronotal seta subequal to anteroangular seta, antennal style stout, and straight and tapered mouthcone. *Frankliniella gossypiana* differs by having a narrower head (1.3 times as wide as long), larger comb of tergite VIII, and narrowly spaced occipital striae. Another closely related species is *F. gemina* Bagnall, a common general feeder from South America, that differs by having a distally recurved and bulky mouthcone with its tip not extending beyond the mentum in dorsal view.

SYNONYMS: While this species remained in obscurity, it was twice described under different names, *F. pseudotritici* Priesner from Mexico (Federal District, Veracruz) and *inornata* Moulton from Cuba. The type series of both species on loan from Senckenberg Museum (SMF) and CAS were compared with that of *bruneri*.

DISTRIBUTION AND BIONOMICS: A long series from Jamaica (Sakimura) and other long series from Cuba and Mexico (USNM, CAS) revealed that

bruneri is widely distributed on the islands of Cuba and Jamaica, and from southern Texas to southern Mexico along the Gulf coast, further south from Yucatan to Costa Rica (SMF), and probably also into Panama and Colombia. So far no specimen of this species from southern Florida has been seen. However, its distribution is very likely extended over southern Florida. This is a common and abundant general flower feeder with a very large host range including many ornamental, crop and uncultivated plants. This species has long been known to be common among cut flowers imported from Mexico to the U. S. All specimens were misidentified in the USNM Collection as *F. trehernei* Morgan by the late D. Moulton. Additional notes on its bionomics are being prepared by the author.

Frankliniella kelliae Sakimura, New Species
(Fig. 5-8)

This species had long been confused with *F. difficilis* Hood, 1925, and remained unstudied until quite recently. The earliest specimens discovered in the USNM Collection were collected in 1912 at Key West, Florida, and again in 1915 at Santiago de las Vegas, Cuba. The latter (Cardin 1918: 58) was submitted for determination to Hood who left them unnamed. Several other subsequent specimens (USNM, CAS) were found misidentified as *F. difficilis* or *tritici* (Fitch), or left undetermined. The first critical study was made by Kellie O'Neill in 1965 with the material collected by the present writer from Jamaica. Her conclusion was that they represented a closely related but separate species from *difficilis*. By a mere coincidence, 5 specimens of this species were found mounted together with the type series of *F. bruneri* collected in 1924 at La Jaula, Cuba (Table 1). A new species is designated here, and is named after Kellie O'Neill in appreciation of her broad knowledge on the vast numbers of the American species of *Frankliniella*. Measurements given in the following description are based on samples from 11 different populations (12♀♀, 3 ♂♂) from Jamaica and 2 others (4 ♀♀, 2 ♂♂) from Cuba.

Brief Diagnosis: *Tritici* group—*difficilis* subgroup. Yellow body without any abdominal blotching, ocellar crescent brownish, antennal III with mushroom form pedicel, anteromarginal pronotal seta subequal to anteroangular seta, comb of tergite VIII always complete but sometimes very short, caudal setae nearly subequal to each other, male with discal seta on tergite IX well developed and far larger than seta IXi, without comb on tergite VIII. Easily confused with *F. difficilis* in female, but distinct in male.

Description: *Female including holotype*: Pale yellow body without any brown blotching on abdomen, muscle marks on tergites III-VII as in *F. bruneri* (Fig. 3), clearly visible but rarely not; antennal I pale, II-V yellow, distal 2/3 of II grayish brown washed, distal 1/3 of III and extreme of V brown washed, distal 3/4 of IV dark grayish brown, VI-VIII dark grayish brown; ocellar crescent brownish; wings pale yellow; major setae brown to dark grayish brown; integumental sculptures inconspicuous except at sides of tergites and laterotergites. Body 1370-1660 (1610) (measurement in parentheses following the range denotes holotype or allotype); head (Fig. 5) 97-112 (112), w. 140-158 (156), 1.4-1.5 times as wide as long; mouth

cone rather short, straight and tapered; interocellar 39-54 (43), 0.3-0.5 of head, variable, near the outer common tangent of anterior and posterior ocelli; postocular iv 28-39 (39), 0.6-0.9 of interocellar, variable. Antenna (Fig. 6) 256-292 (292), 2.5-2.6 times as long as head; II 37-41 (41), w. 22-24 (24), 1.6-1.8 times as long as wide, dorsoapically somewhat elevated but hardly produced; III 49-59 (56), w. 18-21 (20), 2.6-3.0 (2.8) times as long as wide, pedicel (Fig. 7) in regular mushroom form; style stout (VII+ VIII / VII w. = 2.6-2.9); length (width) of all segments of holotype: 28 (28). 41(24), 56(20), 50(18.5), 38(18.5), 49(17), 7(7), 10(5.5). Pronotum (Fig. 5) 117-133 (133), w. 153-191 (186), 1.4-1.5 times as wide as long, 1.1-1.2 of head; anteroangular 51-64 (64), 0.4-0.5 of pronotum, anteromarginal 44-59 (59), 0.8-1.0 of anteroangular, usually subequal but rarely a little smaller, somewhat variable, 4 minor setae between anteromarginals; posteroangular i 60-79 (76), ii 51-68 (68), subequal, 0.4-0.6 of pronotum, posteromarginal ii 33-50 (50), 0.3-0.4 of pronotum. Pterothorax 184-212 (204); forewing 600-790 (750), with 14-18 setae but usually 15-16 on hind vein; hind tibia 153-179 (179). Abdomen 870-1070 (1070), ctenidia and discal setae on tergites normal for the genus, comb on tergite VIII always complete but variable in length (5-12), ovipositor 198-225 (222); caudal setae: IXi 77-102 (91), ii 90-120 (105), iii 89-115 (100), Xi 99-113 (111), ii 84-105 (102), subequal each other.

Male including allotype: Body paler than ♀, antennal I pale, II-III and V yellow, nearly without brown or gray wash at all, IV yellow with distal 1/2 grayish brown, VI-VIII grayish brown, VI sometimes lighter at extreme base; without muscle marks. Body 920-1180 (1180), head 101-106 (106), w. 130-138 (138), 1.3 times as wide as long, interocellar 36-40 (39), postocular iv 24-33 (29), antenna 238-252 (252), both II-III similar in length / width to ♀. Pronotum 145-153 (153), w. 105-111 (111), 1.4 times as wide as long, anteroangular 40-49 (45), anteromarginal 41-44 (43). Comb on tergite VIII absent, glandular areas on sternites III-VII large, transverse, oblong; genitalia about 93. Caudal setae (Fig. 8): IXi 15-19 (19), discal 54-60 (54), IXii 45-53 (53), iii 39-46 (43), clasper 62-73 (73), the first 2 in thick seta form with discal far larger than i, the last 3 in blackish thorn form and thickness somewhat variable among specimens.

TYPE: Holotype ♀, allotype ♂, Jamaica, Kingston, Hope Garden, *Tithonia diversifolia* fl., 15-XI-1964, K. Sakimura (Saki 4408-1 ♀, —3 ♂) USNM Type 100069). Paratypes: same data, 1 ♀, 2 ♂♂; same locality and date, *Blighia sapida* fl., *Bauhinia triandra* fl., *Calophyllum inophyllum* fl., and *Caesalpinia coriaria* fl., 16 ♀♀; Bryan Castle, *Eupatorium odoratum* fl., 1 ♀; Bengal, *Lantana camara* fl., 1 ♀; Falmouth, *Canavalia rosea* fl., 3 ♀♀; Round Hill, Barnett, Bengal, and Woodstock, all from *Cocos nucifera* male fl., 7 ♀♀; Hope Garden, *Cassia siamea* fl., 3 ♀♀; all these 32 ♀♀, 2 ♂♂ paratypes: 15-XI-8-XII-1964, Sakimura (Saki 4404a, 4408, 4410c, 4411, 4416, 4449c, 4454a, 4455a, 4476, 4477, 4520a, 4530a), R. Latta (Saki 4494) (Sakimura).

OTHER SPECIMENS EXAMINED: *Jamaica*: Bog Walk, "net", 2-II-1937, E. A. Chapin, 1 ♀ (USNM). *Cuba*: Santiago de las Vegas, citrus fl., and *Carissa acuminata* fl., 23, 26-IV-1915, P. G. Cardin (Hood 93, 94, 99), 3 ♀♀, 2 ♂♂ (USNM); La Jaula, orange and avocado, 6-IV-1924, S. C. Bruner (mounted together on 2 slides of Watson's type series of *F. bruneri*), 3 ♀♀, 2 ♂♂

(measured) (FSAC); Baragua, citrus fl., and *Nerium oleander* fl., 7, 10-IV-1927, L. C. Scaramuzza, C. F. Stahl (Moulton 1850, 1851), 1 ♀, 1 ♂ (measured) (CAS). *Florida*: Key West, 23-IV-1912, G. A. Runner and A. C. Morgan, 1 ♀ (USNM); Big Pine Key, "flowers", 27-XII-1950, J. D. Hood (Hood 1928), 1 ♀ (USNM). *Bahamas*: Nassau, lantana, VI-1956, N. L. H. Krauss, 5761, 1 ♀, 1 ♂ (USNM). *Dominican Republic*: Porto Libertador, citrus, 14-VI-1952, C. Dowling #44, 52-6604, 7 ♀♀, 1 ♂ (USNM). *Puerto Rico*: Rio Piedras, 8-IX-1947, G. N. Wolcott, 47-12970, 2 ♀♀ (USNM).

DISTRIBUTION AND BIONOMICS: The above data indicate that collections were made from Florida, Bahama, Cuba, Jamaica, Dominican Republic, and Puerto Rico. The species is apparently distributed widely in the central Caribbean area, and is a very common general flower feeder. Additional notes on its bionomics are being prepared by the author.

RELATIONSHIPS: *Frankliniella kelliae* and *difficilis* are closely related and have only a few distinguishing features such as color of the ocellar crescent and, in the male, the comb of tergite VIII and chaetotaxy of tergite IX. Muscle marks are present in both species but apparently are less common in *difficilis*. When the male is not collected together with the female and the ocellar crescent is faded on the mounted specimens, there has been and will be no way to make a reliable separation between them. *Frankliniella difficilis* differs from *kelliae* by having a red ocellar crescent, and, in the male, by having a short but complete comb with both IXi and discal setae being in a thorn form of subequal lengths (about 25-30 μm long).

Another allied species is *F. tritici* that is often lacking the brown abdominal blotchings of the pale form in the Caribbean area. It differs from *kelliae* by having shorter anteromarginal pronotal seta than anteroangular seta, and incomplete comb on tergite VIII.

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BIONOMICS OF THE BROMELIAD-INHABITING MOSQUITO *WYEOMYIA VANDUZEEI* AND ITS NURSERY PLANT *TILLANDSIA UTRICULATA*[1]

J. H. FRANK[2] AND G. A. CURTIS[3]

ABSTRACT

Aquatic stages of the mosquito *Wyeomyia vanduzeei* Dyar & Knab inhabit leaf axils of the epiphytic bromeliad *Tillandsia utriculata* L. in southern Florida.

Rough-barked trees provide a substrate for *T. utriculata* and a habitat for *W. vanduzeei.* The volumetric capacity of *T. utriculata* leaf axils can be estimated from length of longest leaf (volumetric capacity in ml = 0.003251 x leaf length in $cm^{2.7799}$). In each plant, older, larger axils provide most of the volumetric capacity, but the outermost axils lose their ability to retain water. Water entering bromeliad axils is throughfall, i.e. rainfall reduced in volume but enriched with nutrients as it penetrates the tree canopy (throughfall mm = —0.2715 + (0.8825 x rainfall mm) in a high marsh study area). Organic debris from the tree canopy (estimated annual mean 2.4 g/m^2/day in a high marsh study area), trapped and decomposed in the bromeliad axils, also provides nutrients for aquatic organisms and for the bromeliad. The perennial bromeliad provides a stable habitat for mosquito larvae.

The number of mosquito eggs laid in axils is influenced by the size, water content, senescence and flower production of the bromeliad; as many are laid in the smaller, inner axils as in the larger, outer axils. At 27°C, most floating eggs hatched within 48 and 96 h. Eggs stranded out of water suffered loss in numbers and in viability, with combined loss at 10 days of 49%, at 20 days of 77%, and at 30 days of 95%

RESUMEN

En el sur de la Florida (EUA), los estadios acuáticos del mosquito *Wyeomyia vanduzeei* Dyar & Knab habitan en las axilas de las hojas de la bromelia epifítica *Tillandsia utriculata* L.

Arboles con la corteza rugosa proveen un substrato para *T. utriculata* y un habitat para *W. vanduzeei.* La capacidad volumétrica de las axilas de las hojas de *T. utriculata* puede ser estimada del largo de la hoja mas larga (capacidad volumétrica en ml = 0.003251 x largo de la hoja en $cm^{2.7799}$). En

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cada planta, las axilas mas viejas y mayores proveen la mayoría de su capacidad volumétrica, pero las axilas exteriores pierden la capacidad de retener agua. El agua que entra en las axilas es la caída pasante, es decir, lluvia reducida en volumen, pero enriquecida con nutrientes al penetrar la bóveda del follage (caida pasante en mm = —0.2715 + (0.8825 x mm de lluvia) en una zona de estudios en la parte mas elevada de una marisma.)

Escombro orgánico de la bóveda de los árboles (caida media anual 2.4 g/m^2/dia en una zona de estudios en la parte elevada de una marisma), atrapado y descompuesto en las axilas de las bromelias también provee nutrientes a los organismos acuáticos y a las bromelias. La bromelia perenne provee un habitat estable para larvas de mosquitos.

El número de huevos de mosquitos depositado en las axilas es influenciado por el tamaño, contenido de agua, senectud, y producción de flores de la bromelia; la misma cantidad de huevos es depositada en las mas pequeñas axilas interiores que en las mayores axilas exteriores. A 27°C, la mayoría de los huevos flotantes eclosionan dentro de un periodo de 48-96 h. Huevos varados fuera del agua sufrieron pérdidas en números y en viabilidad, con pérdidas combinadas en 10 dias de 49%, en 20 dias de 77%, y en 30 dias de 95%.

Immature stages of hundreds of mosquito species have been recorded from water-containing leaf axils of numerous bromeliad species in the neotropics. Mosquito-bromeliad associations are less complex in southern Florida where the neotropical fauna and flora are depauperate. The mosquitoes *Wyeomyia vanduzeei* Dyar & Knab and *Wyeomyia mitchellii* (Theobald) alone represent more than 100 neotropical *Wyeomyia* species. *Tillandsia utriculata* L. is 1 of 2 common, indigenous bromeliads holding water in their axils, and represents a family of over 2,000 neotropical species. This paper describes aspects of the ecology of *W. vanduzeei* and its nursery plant, *T. utriculata.*

Tillandsia utriculata As a Mosquito Nursery

Distribution and Habitats

This bromeliad occurs in southeastern Georgia, Florida, the West Indies, Mexico, Central and South America (Small 1933). In southern Florida it is an abundant epiphyte of rough-barked trees such as oak (*Quercus* app.), cypress (*Taxodium* spp.) and buttonwood (*Conocarpus erecta* L.) (Butler 1974). Our observations concern mainly high marsh (Provost 1974) near Vero Beach, Florida (27° 38′ N, 80° 23′ W), but some relate to the adjoining landward area. The mature buttonwoods in our study area do not exceed 4 m in height, while oaks of the adjoining landward area exceed 12 m. Thus, *T. utriculata* has a greater vertical range on oak. The tree trunk and branches supply anchorage, and the canopy supplies nutrients and protection from frost. Even though some tillandsioid bromeliads are well-adapted to high levels of solar radiation (Pittendrigh 1948, Benzing and Renfrow 1971), *T. utriculata* normally were exposed to little direct solar radiation in our study area because of the evergreen buttonwood canopy. The live oaks (*Quercus virginiana* Mill.) of the landward area also are evergreen. Abnormally low temperatures occurred in our study area in January 1977, but no damage to the bromeliads was seen, whereas canopies of buttonwood were

damaged severely by frost. *Tillandsia utriculata* plants left above the level of the frost damage were directly exposed to solar radiation, and nutrient input eventually was reduced; many lost greenness, many died, and others flowered at an usually small size. The bromeliad appears normally to grow only under tree canopies.

After storms, the ground under live oaks is littered with branches and bromeliads. The latter seldom survive long, and are eaten by rabbits (eastern cottontail, *Sylvilagus floridanus* Lyon). Casual observation suggests that buttonwoods suffer few storm-lost branches, but if bromeliads fall from buttonwood, they are also eaten by rabbits (marsh rabbit, *Sylvilagus palustris* (Bachmann)). The abundance of *T. utriculata* probably is limited by available habitat, climate, and dispersive abilities of seed.

Structure

Tillandsia utriculata plants (Fig. 1) mature several years after germination and after one season's seed production. The growing plant produces leaves at its apex in a clockwise spiral, where each subtends an angle of about 137° to its antecedent with reference to the plant's axis. The newest leaves are small and slender regardless of the plant's size. Older leaves may measure more than 10 cm across their bases and may exceed 1 m in length. As the plant grows, the oldest leaves die sequentially; thus the base of a plant may be shrouded in dead leaves which hold humus in their axils.

The leaf bases overlap broadly and fit closely at their edges. The living leaves, except the outermost, trap water in their axils. Each small body of water has a crescent-shaped surface area determined by the curvature of the leaf base around the plant axils, and each body of water is narrowest at its deepest point, where the leaf is attached. In a plant containing visible quantities of water, the surface is at a lower level in older, larger axils than in newer, smaller ones. Water poured into the center of a dry plant fills each axil in turn, and the excess flows sequentially into the larger axils below.

In older plants, bases of about 50% of the green leaves, the inner ones, are fleshy and brittle; these axils together have less than 20% of the total water-holding capacity, and the water bodies of the innermost majority of them are not discrete. The bases of the remaining 50% of the green leaves are fibrous; the outermost half of these hold no more than drying humus, so that up to 80% of the water-holding capacity is due to only about 25% of the axils; these 25% hold discrete bodies of water and form clusters of phytotelmata (Varga 1928). Very small plants have few leaves and trap no water. Small plants hold water only during wet weather. Large plants hold water at all times, even though water level may be low during drought. Total water volume in axils of the largest plants may exceed 1.3 liters.

The length of the longest leaf was used as a measure of plant size, because this was determined easily without disturbance of axil contents. Total volumetric capacity of axils was compared by measuring longest leaf length to the nearest 1 cm and volumetric capacity to the nearest 5 ml in 98 experimental plants (Frank et al. 1977). A power curve regression ($y = a' x^b$) gave a better fit to the data (Fig. 2) than did either a linear ($y = a' + bx$) or exponential ($y = a' e^{bx}$). The accepted power curve regression ($a' = 0.003251$, $b = 2.7799$, $N = 98$, $F = 277.46$) gives estimated volumetric capacity (y) when leaf length (x) is known.

Fig. 1. *Tillandsia utriculata* plant cut to show form of leaf axils.

GROWTH RATE

Growth of 100 plants of different sizes was followed for 536 days. Plants growing on the north side of live oak trunks were considered separately from those on the south side. Five plants were selected and marked in each size range 0-5, 5-10, . . . 45-50 cm, based on length of longest leaf, giving a total of 50 plants each in positions with northern and southern aspects, at various heights from the ground. Longest leaf measurements were taken on 14-XI-1974 and on days 109, 214, 337 and 536 thereafter. During the entire

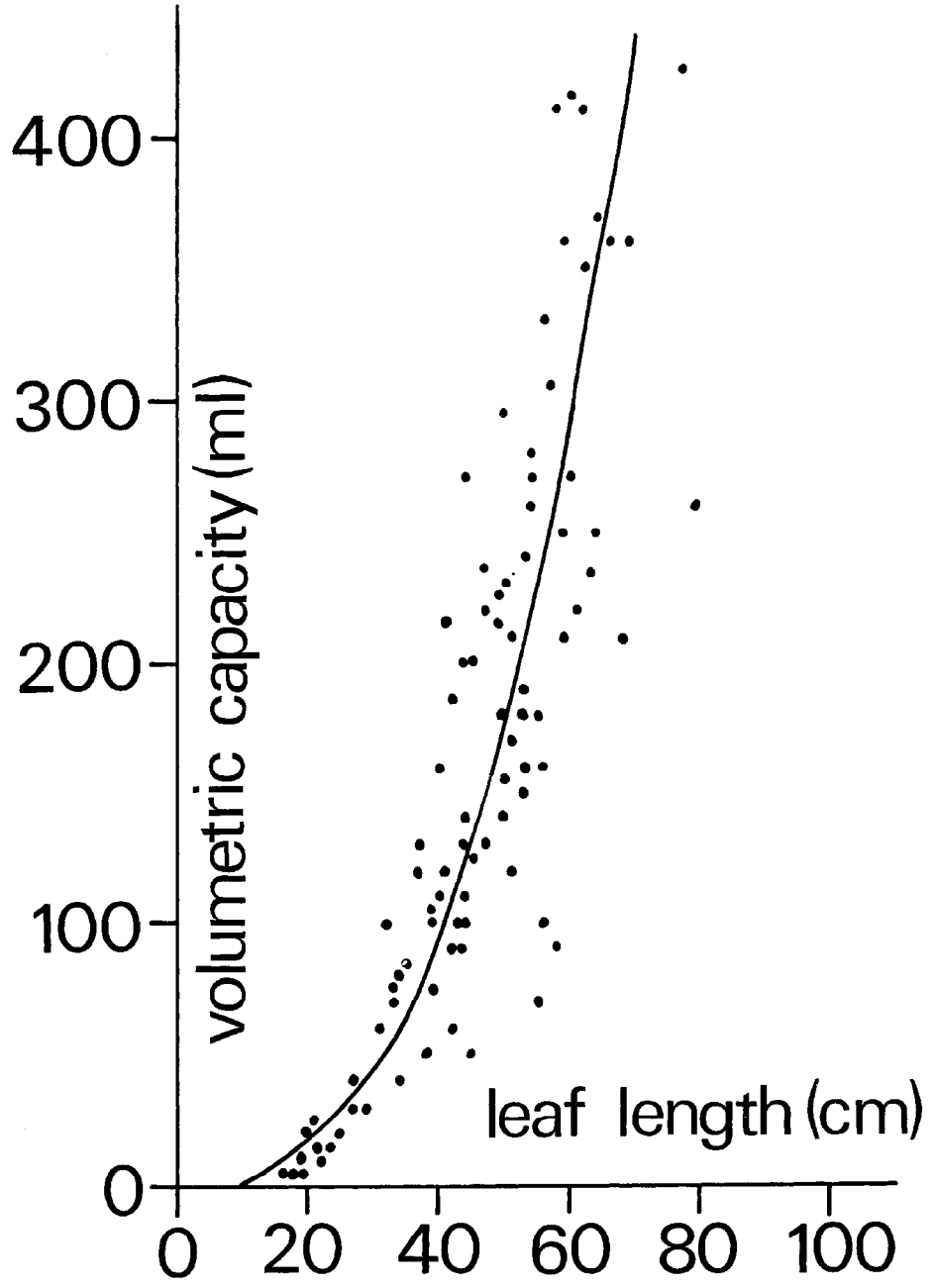

Fig. 2. Scattergram with fitted regression line ($y = a' x^b$) relating volumetric capacity of *Tillandsia utriculata* to length of longest leaf.

period, 17 plants died or fell from their anchorages from natural causes. There was no significant correlation between mortality and size ($N = 10$, $r = 0.2596$, $P > 0.4$), and no significant difference in mortality or dislodgement of plants on the northern vs. the southern aspects ($N = 20$, $t_1 = 0.5797$, $P > 0.5$). Annual mortality (within each of the size ranges separately), was roughly 14% (SD 14.3).

A linear regression of leaf length vs. time was calculated and plotted for each of the 10 size ranges. There was no evidence of curvilinearity, and none of the standard errors exceeded 4% of the value of each coefficient. These regression coefficients were plotted against mean leaf length of plants in each size range, and another linear regression was calculated ($a' = 0.0017$, $b = 0.00078$, SE of $b = 3.206 \times 10^{-7}$). Daily percentage increment of leaf length is thus 0.078%, and future leaf length = $x_t = x_0 (1 + b)^n$, where x_t = leaf length at time t in the future, x_0 = present leaf length, b = rate of increase (0.00078), n = period (days) from time x_0 to x_t. Table 1 was compiled from estimates made by this formula, according plants of 2 cm leaf length to time zero years. Actual leaf length at germination is about 2 mm.

WATER

The canopy of the high marsh study area consists of intermingled foliage of buttonwood, white mangrove (*Laguncularia racemosa* Gaertn.) and black mangrove (*Avicennia germinans* (L.)), and is sparse relative to that of oak in the adjoining landward area. Rainfall and throughfall were measured using 20 galvanized metal rain gauges, precise to the nearest 5 ml (0.2 mm). Using a stratified random distribution system 5 gauges were placed in the open to measure rainfall, and 15 under the tree canopy to measure throughfall, the latter away from gaps in the foliage. Gauges in the open were examined every morning during a period of 6 weeks in September-November 1976 and, when water was present, measurement was made of the volume in all 20 gauges.

Standard deviations of means of each day's rainfall measurements were very low, so each mean (x) for rainfall was treated as a single value when linear regression of throughfall (multiple y values) on rainfall (x) was

TABLE 1. PARTIAL LIFE TABLE DATA FOR *Tillandsia utriculata*.

Time (years)	Length of longest leaf (cm)	Volumetric capacity (ml)	Survival (%)	Population structure (%)
0	2.00	0	100	16
1	2.66	0	86	13
2	3.53	0	74	12
3	4.70	0	64	10
4	6.24	1	55	9
5	8.30	1	47	7
6	11.03	3	41	6
7	14.66	6	35	5
8	19.49	13	30	5
9	25.91	28	26	4
10	34.43	61	22	3
11	45.77	134	19	3
12	60.84	296	16	3
13	80.87	654	14	2
14	107.49	1442	12	2

performed ($a' = 0.2715$, $b = 0.8825$, $Nx = 11$, $Ny = 11 \times 15$, $F = 3{,}540$). The linear regression explains almost all of the difference between sets, and a better fit would not be expected by curvilear regression. However, the value of a′ is very small and analysis of variance showed that it is not significantly different from a zero intercept. If the intercept really is zero, then throughfall must be considered a constant percentage of rainfall. Reynolds and Leyton (1963) gave evidence that when rainfall occurs, it must exceed a small value (the value of a′, as a positive figure, termed canopy saturation), before any penetrates the tree canopy. Accepting this interpretation, then the relationship of throughfall as a percentage of rainfall to rainfall is curvilinear, and rises to an asymptote. This asymptote is calculated as 100 X the value of b (i.e. 88%), and compares with values of about 79% (winter) and 81% (summer) obtained by Trimble and Weitzman (1954) for throughfall in a deciduous forest in West Virginia (Geiger 1971). Apparently, the sparser tree canopy in our study area permitted more throughfall at the asymptote. The value for canopy saturation was about 0.3 mm in our study area, and in the West Virginia study it was about 0.2 mm in winter and about 0.4 mm in summer (Trimble and Weitzman 1954). In our study area, throughfall is available for catchment by bromeliads situated under the tree canopy, and derives from annual average rainfall of ca. 1,500 mm.

Debris Catchment

In the high marsh area in 1976, 400 selected *T. utriculata* plants of maximum leaf length between 40 and 50 cm were used for an investigation of a *W. vanduzeei* population. Plants were hung, in pairs, by nylon string from the limbs of buttonwood and white mangrove. The perimeter of each plant was taken as the position where the curvature of large leaf blades became horizontal, and average diameter was about 25 cm. Thus, catchment area was about 491 cm^2.

Estimates were made of plant debris (leaves, twigs, seeds) falling over a circle of 25 cm diameter beneath the tree canopy. Plastic plant pots of diameter 25.4 cm and depth 24 cm were used as catchment baskets. Drainage holes in the pots were taped over to retain fine particles, and a pot was tied adjacent to and at the same height as each of the 200 pairs of *T. utriculata*. From January 1976, debris was removed from each pot at fortnightly intervals, and 10 of the 200 collections, chosen by stratified random sampling plan, were stored separately and air-dried for 3 weeks at room temperature. Dry samples were weighed, and means and 95% confidence limits were calculated; these values are further converted to g/m^2/day in Fig. 3.

Measurements ended in November 1976, less than a full year later, because of time restrictions. Results were thus from 21 sets, each of 10 samples. These were assigned to spring (the 7 sets up to and including 7 May), summer (the next 7 collections), and autumn (final 7 collections). The spring samples weighed significantly less than summer samples ($t_i = 3.8642$, $P < 0.001$), and significantly less than autumn samples ($t_i = 3.5272$, $P < 0.001$), but there are no significant differences ($t_i = 0.0343$) between summer and autumn samples.

Pool et al. (1975) reported that highest rates of litterfall in mangrove

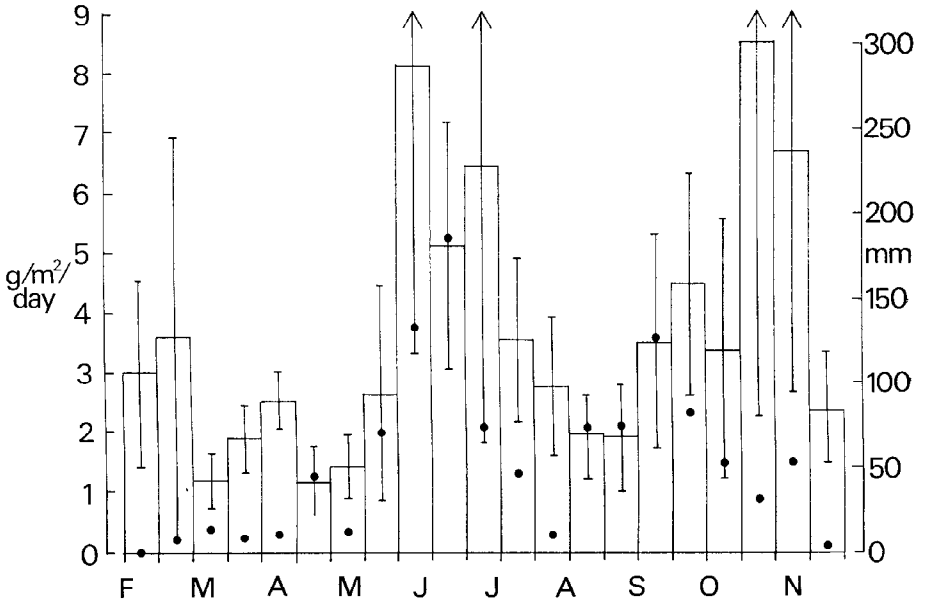

Fig. 3. Histogram showing mean and 95% confidence limits of fortnightly collections of organic debris fallen from tree canopy in high marsh study area. Dry weight is given as g/m²/day. Dots indicate total rainfall in mm during the same fortnightly intervals.

forests corresponded with annual peaks of wet season and frequent wind storms. Total fortnightly rainfall (in mm), from a standard rain gauge about 0.6 km from the study area, is indicated in Fig. 3. Mean debris sample weight does not quite achieve a significant correlation with rainfall (1-tailed, $r = 0.3610$, $P < 0.1$). A similar procedure performed on a daily basis might have yielded a significant correlation.

Pool et al. (1975) measured litterfall in mangrove forests at several localities in southern Florida and Puerto Rico, and found that annual fall ranged between 0.2 and 3.96 g/m²/day between localities, with a mean of 2.2 g/m²/day over all localities. The present data do not cover an entire year, but the mean litterfall for the period considered is 3.62 g/m²/day. If litterfall over the period from November to January is assumed to be at the same rate as from February to May, the annual figure for the study area was about 2.4 g/m²/day. According to Pool et al. (1975), the rate of litterfall in mangrove ecosystems is higher than in surrounding ecosystems. Thus, bromeliads in mangrove ecosystems should trap more debris than should those in adjacent inland areas.

Nutrients

Tillandsia utriculata plants use nutrients from debris, leachates, and possibly stemflow. Solid materials trapped include leaves, twigs, seeds and pollen of trees, as well as excreta of lepidopterous larvae feeding on the trees. Additional materials may come from associated vines and from other trees intermingled in the canopy. Use by bromeliads of leachates from tree canopies was demonstrated by Tukey (1970). Types of nutrients in through-

fall were investigated by Voigt (1960), Carlisle et al. (1966), and Tukey (1970), but not for mangrove ecosystems. Carlisle (1967) studied oak stemflow, which also contains nutrients. Some *T. utriculata* plants may be suitably positioned on oak trunks to be able to trap stemflow, but those on the more horizontal branches of oak, and on buttonwood seem poorly positioned to use this resource. Throughfall from the salt-coated canopy of black mangrove apparently is deleterious to *T. utriculata* (Frank and Curtis 1977b), and in the present study bromeliads have not been found growing on black mangrove, yet Lugo and Snedaker (1974) stated that this association occurs.

The chemistry of water held in axils of bromeliads was investigated by Laessle (1961), McWilliams (1970), Benzing (1970, 1973), Benzing, Derr and Titus (1972) and Benzing and Renfrow (1974). The water is acid, and in most instances bromeliads absorb nutrients by means of trichomes (absorbing scales). An ecological classification of bromeliads according to method of nutrient uptake was initiated by Pittendrigh (1948) and expanded by Rauh et al. (1973) and Benzing (1977).

In the laboratory, organic debris added to bromeliad infusion water produces a bacterial scum, but addition of aquatic insect larvae, e.g. mosquito larvae, causes the scum to be removed, at least in part by feeding by the insects. Continued presence of insect larvae eventually causes exhaustion of the nutrient supply, and the infusion water becomes clear. Aquatic organisms may compete with bromeliads for nutrients, and emerging adult insects bring about a removal of nutrients from the microhabitat. At the same time, digestion of particulate matter by the insects must contribute to the partial breakdown of nutrients, making these more readily available to the plants.

Wyeomyia vanduzeei

Oviposition

Adult *W. vanduzeei* of both sexes perch on the most shaded side of tree trunks. Preference for shade tends to keep mosquitoes under tree canopies, in the vicinity of bromeliads. Females lay their eggs singly while in flight. Oviposition flight is jerky and bobbing and is performed in and above bromeliad axils, presumably allowing a rapid response of the female mosquito to external stimuli. The air space above the central axils of *T. utriculata* is not limited by any part of the plant, except when a flower spike is produced. The air space above the larger, outer axils may be limited by downcurvature of leaves above, thus hindering oviposition.

Mosquito flight was observed in relation to a caged *T. utriculata* plant of about 120 ml capacity from which the distal portions of the longer leaves had been cut. Successive bobbing flights over the axils were timed, some over the inner axils and some over the outer axils. Seventeen flights of average duration 14 sec (SD 14) occurred over the inner axils and 19 flights of average duration 10 sec (SD 13) over the remaining axils. Thus, inner axils, containing a much smaller volume of water, attracted a similar number of flights of similar duration as did outer axils. Disproportionately large oviposition in inner axils is likely to increase the probability of egg survival, because central eggs are in less danger of being washed from the

plant during heavy rainfall (Frank and Curtis 1977b). We envisage a progression of eggs and larvae from inner to outer axils, partly as a result of rainfall so distributing the eggs, partly as a result of plant growth, and in the absence of any indication that either eggs or larvae move in the reverse direction.

To test plant quality on oviposition, we selected pairs of dying and healthy plants of similar (within 5 ml) volumetric capacity. Each dying plant had roughly 70% of leaf surfaces browned (necrotic). A comparison (Table 2) of number of eggs laid was performed using the methods of Frank et al. (1976). Significantly more ($P < 0.001$) were laid in healthy plants.

Because *T. utriculata* plants die after flowering, the presence of a flower spike, even if a plant has no browned leaves, portends approaching death. Using the same method as above, oviposition was compared (Table 2) in pairs of matched plants where 1 member of each pair had a flower spike, and the second did not. Both members appeared healthy and without browned leaves. Significantly more ($P < 0.05$) were laid in plants without flower spikes.

We have demonstrated (Frank et al. 1976) that oviposition is affected by plant size and by presence of water in the leaf axils, but that presence of organic infusion, or infusion plus organic debris, appears to have no affect.

Eggs

Wyeomyia vanduzeei eggs float, aided by a waxlike flotational device (Frank et al. 1981). Advantages of floating may be associated with dis-

TABLE 2. Results of oviposition tests using caged mosquitoes and pairs of plants matched for volumetric capacity. More eggs were laid in healthy plants than in dying plants ($t_d = 4.5663$, $P < 0.001$). More eggs were laid in plants without flower spikes than in plants with flower spikes ($t_d = 2.5840$, $P < 0.05$).

		Number of mosquito eggs laid			
		Health of plant		Presence of flower spike	
Pair	Trial	Healthy	Dying	Without	With
1	1	168	46	634	82
	2	326	97	326	420
	3	476	114	486	385
	4	651	124	576	512
2	5	161	83	594	531
	6	225	112	1362	683
	7	142	50	266	288
	8	201	33	1025	794
3	9	142	45	154	137
	10	114	16	933	297
	11	163	13	595	462
	12	154	47	267	227

tribution towards outer axils, or with avoidance of submerged predators, or with respiration. Other advantages of the device may be in plastron respiration if trapped below the water surface, in protection from terrestrial predators, or in reduced desiccation if stranded above the water line. Stranded eggs do not hatch until inundated by rainfall.

To test affects of stranding above water on viability, a series of plants of similar volumetric capacity was assembled. Replicated treatments using methods similar to those of Frank et al. (1976) compared number and viability of eggs recovered from bromeliads stored for 10, 20 or 30 days after oviposition with paired controls. Before experimental use, plants were cleaned and submerged in water for 24 h to remove their fauna, then shaken in air to remove most of the water, but allowing sufficient to remain to stimulate oviposition by caged mosquitoes. After 24 h in a cage of mosquitoes, eggs in the control plant were extracted, counted and tested for viability by attempting to hatch them in a standard way in dishes of water at 27°C.

Mean viability of eggs extracted from control plants was 88.3 ± 6.2% (30 replicates). Most of these eggs hatched within a period between 48 and 96 h from oviposition (Fig. 4). In the stored plants, the recoverable percentage of eggs was approximately halved every 10 days, and although the viability of eggs recovered was little reduced after 10 days, it was reduced sharply by 30 days (Table 3). The stored eggs which hatched did so within minutes of placement in water, suggesting that embryonation occurred during storage and thus out of water. A negligible percentage of eggs could be expected to survive a drought of 30 days under field conditions, though survival might be better at lower winter temperatures.

Behavior of Larvae and Pupae

Dissections of digestive tracts of late instar larvae revealed mainly fragments of organic, particulate matter, with algae, fungal spores, and pollen in lesser quantities. Density of larvae, but not eggs is dependent upon plant size, suggesting density-dependent competition (Frank et al. 1977). By food-dependent delay of development, especially in instar III, the larvae spread the risk of starvation in time (Frank and Curtis 1977a).

If density of larvae should vary from one axil to another, it is relevant to know whether the larvae are able to move from axil to axil and thus discover additional food. O'Connor (1923) wrote that the larva of the mosquito *Aedes kochi* (Doenitz), found in plant leaf axils in the Indo-Pacific region, can leave the water and "creep like a caterpillar", accomplished by special antennal structures. Peters (1956) reported that the larva of the mosquito *Uranotaenia ornata* Theobald, which inhabits plant leaf axils in Liberia, can crawl out of the water of a container, browse along under the water film that follows it, then turn round and redescend into the container. Although some insect larvae present in *T. utriculata* axils can climb out of water containers (watch glasses, specimen vials), *Wyeomyia* larvae were not observed to do this, and it seems improbable that they can move from one axil to another unless the leaves forming the axils are damaged. However, their ability to delay development according to food availability is surely an adaptation to a relatively stable habitat with intermittent food supply. They

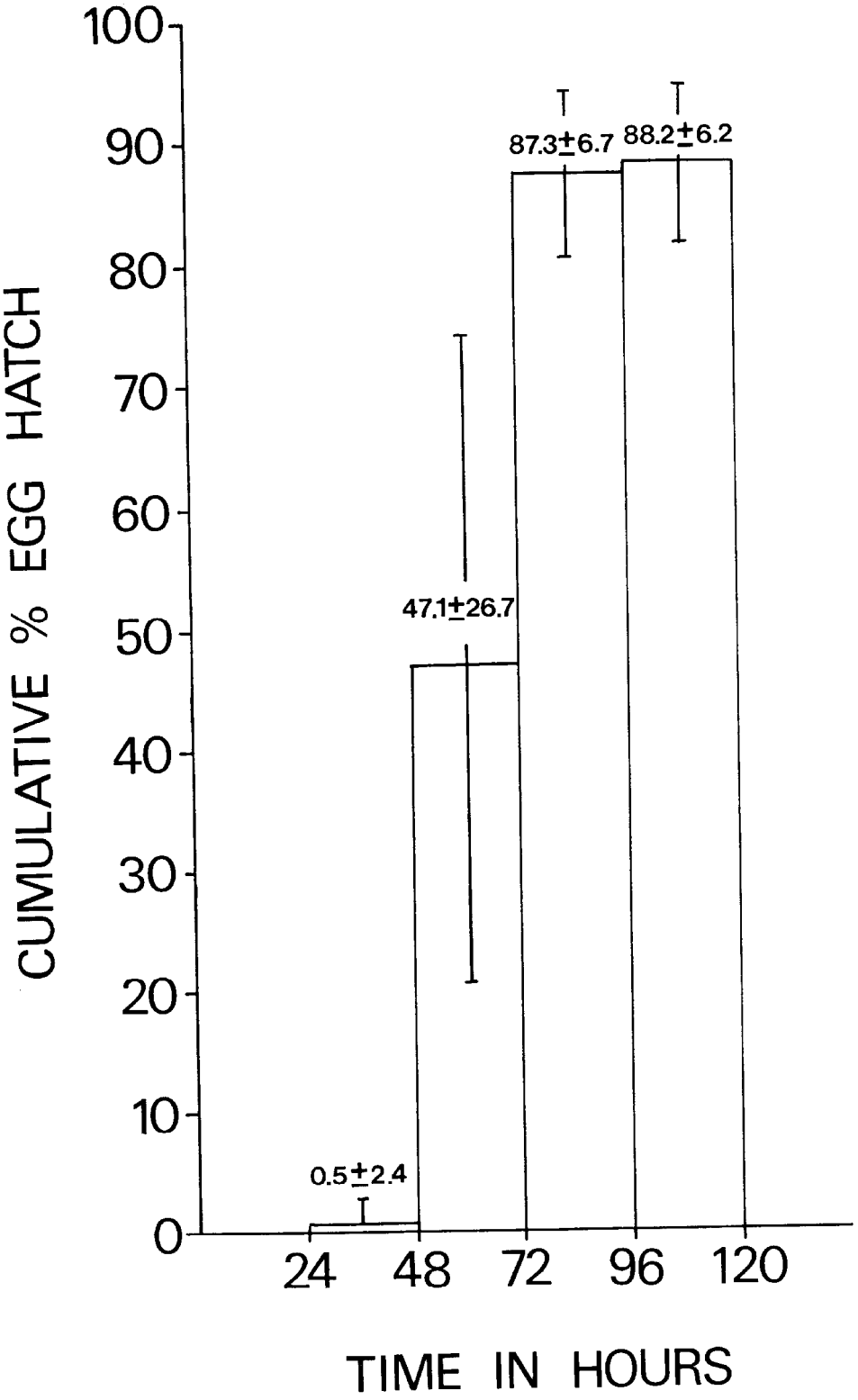

Fig. 4. Histogram showing cumulative % of *Wyeomyia vanduzeei* eggs hatching vs. time after oviposition, based on 30 groups each of 100 eggs at 27°C.

TABLE 3. NUMBER OF EGGS RECOVERED AFTER STORAGE IN BROMELIADS IN HUMID ATMOSPHERE (COMPARED WITH CONTROLS, ± STANDARD DEVIATION), VIABILITY OF EGGS RECOVERED (% HATCHED ± STANDARD DEVIATION, COMPARED WITH CONTROLS) AND COMBINED LOSS FROM BOTH CAUSES.

Storage	Recovery			Viability			Combined
	Control	Treatment	Loss	Control	Treatment	Loss	Loss
10 days	303.4 ± 192.0	160.1 ± 125.3	47%	89.9 ± 5.7	87.6 ± 6.8	3%	49%
20 days	320.5 ± 200.6	83.4 ± 115.8	74%	87.0 ± 4.6	75.7 ± 18.4	13%	77%
30 days	495.8 ± 371.9	63.9 ± 58.4	87%	87.9 ± 8.1	32.3 ± 21.3	63%	95%

are thus adapted for the bromeliad axil habitat just as the locomotive abilities of *A. kochi* and *U. ornata* adapt these larvae for other plant axils.

Wyeomyia larvae and pupae react to disturbance by diving, similarly to larvae and pupae of other mosquitoes. Because of the shape of *T. utriculata* axils (Fig. 1), the mosquitoes are hard to see. Because heavy rainfall constitutes a disturbance, the diving reaction may enable larvae and pupae to avoid being washed out of the plants (in contrast to eggs) (Frank and Curtis 1977b).

Predators and Parasites

The larger axils of bromeliads hold discrete bodies of water. Amphibious predators, able to move from one axil to another, may be better adapted to feed on mosquito larvae. In Florida, aquatic larvae of a muscid fly identified as *Neodexiopsis* sp. (D. Fish, pers. comm.) are amphibious predators in *T. utriculata* axils, but the predatory larvae of the mosquito *Toxorhynchites r. rutilus* (Coquillett) are not amphibious. Tree frogs (*Hyla*) are sometimes present in the larger plants (Neill 1951). In the neotropics, but unknown in Florida, Dytiscidae (Balfour-Browne 1938) and Hydrophilidae (Champion 1913) are amphibious in bromeliads. Terrestrial predators may be able to take advantage of stranded aquatic organisms during times of low water level in bromeliad axils. Staphylinidae and Carabidae, well-represented in bromeliads in the neotropics (Champion 1913, Zaragoza 1974), seem to be absent from this habitat in southern Florida, but ants and spiders are present and probably fulfill a similar role.

Pilosporella fishi Hazard and Oldacre, a microsporidan parasite of *W. vanduzeei* larvae, seems too rare to have a significant effect on the mosquito population (Frank and Curtis 1977c). The fungal parasite *Coelomomyces* sp. also is rare (Hall and Anthony 1979).

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ACTIVITY RHYTHMS, INFLUENCE OF HOST PLANT ON MATING AND OVIPOSITION, AND REARING OF THE SOUTHERN PINE CONEWORM (LEPIDOPTERA: PYRALIDAE)

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Olustee, FL 32072 USA

ABSTRACT

The southern pine coneworm, *Dioryctria amatella* (Hulst), (Lepidoptera: Pyralidae) is nocturnal and reproductive behavior occurs only during the last 5 h of scotophase (12L:12D photoperiod). Mating does not begin until moths are 2 days old and mating and oviposition are dependent on the presence of the host plant. Satisfactory rearing required surface sterilization of eggs with sodium hypochlorite, autoclaving the dietary wheat germ, inclusion of sorbic acid in the larval rearing medium, and a larval rearing density of no more than 2 per 30 ml container. The described methods have been used to rear more than 40 successive generations of the insect on the WGCS medium.

RESUMEN

El gusano de piñón, *Dioryctria amatella* (Hulst), (Lepidoptera: Pyralidae) es nocturno y su funcionamiento reproductivo toma lugar solamente durante las últimas 5 horas del período de oscuridad (12L:12D) fotoperíodo). El apareamiento no comienza hastaque las polillas tengan 2

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días, y el apareamiento y la oviposición dependen de la presencia de la planta hospedera. Una cría satisfactoria requirió la esterillización de la superficie de los huevos con hipoclorito de sodio, germen de trigo esterilizado en autoclave, inclusión de ácido sórbico en el medio de cría, y una densidad de cría larval de no más de 2 por cada envase de 30 ml. Los métodos descritos han sido usados para criar más de 40 generaciones consecutivas de insectos en el medio de WGCS.

Larvae of the southern pine coneworm, *Dioryctria amatella* (Hulst) damage southern pines by feeding on male and female strobili, on vegetative tips, on strobili infected with the rust *Cronartium strobilinum* (Arth.) Hedgc. and Hahn, and on fusiform rust galls caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme* (Cumm.) Burds, et Snow (Ebel 1963, 1965, Neunzig et al. 1964, Coulson and Franklin 1970, Ebel et al. 1975). Larvae pass through 5 instars (Fatzinger 1970a) and require from 3 to 5 weeks to develop to the pupal stage when reared at ca. 24° C on pine cones (Ebel 1965). The species is multivoltine and may have from 1 to 4 generations per year in north Florida (Ebel 1965, Merkel and Fatzinger 1971).

Previous attempts to establish laboratory colonies were only partially successful because of insufficient egg production between generations. Ebel (1959) reared *D. amatella* from the egg to adult stage with procedures developed for *Dioryctria ebeli* Mutuura and Monroe (formerly *D. abietella* (Denis & Schiffermüller)), on waxed conelets of slash pine, *Pinus elliottii* Engelm var. *elliottii*. DeBarr (1968) reared larvae of *D. amatella* on the artificial medium developed by Fatzinger (1968) for *D. ebeli* but could not obtain enough eggs for continuous culture. Merkel and Fatzinger (1966) reared *D. amatella* on slash pine cones and obtained an average of only 30 eggs per female deposited on small fusiform rust galls cut from slash pine branches. Ebel (1965) observed that only 16% of newly emerged females held in mating cages deposited viable eggs during the first 2 days whereas 43% contributed by day 5. DeBarr (1968), however, found that only 10-20% of the females mated in the laboratory whereas about 50% did so in an outdoor insectary.

The study reported here was conducted to optimize the rearing of *D. amatella* by determining its temporal patterns of reproductive behavior, requirements for host plant material to stimulate mating and oviposition, tolerance of increased larval densities, reaction to surface sterilization of eggs with sodium hypochlorite or peracetic acid, and acceptance of sterilized dietary ingredients.

Materials and Methods

A laboratory colony of *D. amatella* was initiated in 1970 with larvae collected from fusiform rust galls of slash pine and eggs from moths that emerged from slash pine cones. The larvae were reared on the WGCS medium developed for *D. ebeli;* constituents include wheat germ, casein, 5 sugars present in slash pine cones, salts, vitamins, 2 mold inhibitors, agar, and water (Fatzinger 1970b). In a slight modification, the medium was thickened by decreasing the water content 25% and the nonessential stach-

yose was eliminated. The hot (95° C) medium was dispensed into either 30 ml plastic condiment cups or sterilized glass test tubes and allowed to cool (gell) prior to initiating rearings of first-stage larvae. The cups were filled to a depth of 1 cm with medium. The test tubes were filled to a depth of 4 cm and gelled at a 30° angle to provide a thickness-dependent moisture gradient which enabled larvae to select optimum conditions for feeding. After the larvae were transferred, the tubes were stoppered with sterile, nonabsorbent cotton and the cups were capped with plastic, snap-on lids. The resulting pupae were separated by sex (Fatzinger 1968) and held on moist paper toweling in wire screen cages (30 x 30 x 30 cm) until moths emerged. The environment for all rearing and experimentation was 27° C, ca. 65% RH, and 12L:12D photoperiod (0600 to 1800 photophase).

Locomotor activity, female calling, and mating behavior were recorded automatically by time-lapse photography (Fatzinger 1973). Moths were photographed through the glass doors of clear plastic cages at 30-min intervals for 7 days.

Host material consisted of cross sections (ca. 6 mm thick x 4 cm dia.) cut from a fusiform rust branch gall. Initially the behavior patterns of 26 ♀ moths and 9 pairs of moths that emerged from field-infested slash pine cones were observed without host plant materials. Behavioral effects of host plant material were observed with moths obtained from the first 15 successive generations reared. These included 9 ♂ observed without galls and 18 ♂, 20 ♀, and 14 pairs observed with galls. The general patterns of behavior were obtained by averaging the observations of all moths regardless of their age. The times of the occurrence of behavioral events are reported as means in hours and minutes ± angular deviations in tenths of hours ($P = 0.01$). These means were obtained by the methods described by Batschelet (1965) for circular normal distributions.

Over a 3-year period, 26 colonies of *D. amatella* were initiated to assess the effect of larval rearing density on colony survival and duration of larval stage. Tests included 11 colonies or 14,045 larvae reared 1 per container (899 in test tubes and 13,146 in cups), 4 colonies or 764 larvae reared 2 per container (140 larvae in test tubes and 624 larvae in cups), and 11 colonies or 28,482 larvae reared 3 per container (4,776 in test tubes and 23,706 larvae in cups).

Eggs and constituents of the WGCS medium were individually plated on sterilized malt agar and nutrient agar media in plastic petri dishes to determine the sources of microbial contaminants. The dishes were held at 22° C and were observed for 2 weeks at 2-day intervals for the growth of microorganisms.

The efficacies of peracetic acid and sodium hypochlorite for sterilizing the egg surfaces were compared. Eggs deposited on cheesecloth were washed for 1 min in a detergent (0.1% sodium alkylarylsulfonate), submersed for 5 min in either 0.1% peracetic acid or 0.5% sodium hypochlorite solutions, and rinsed twice in sterile water. Individual eggs were transferred to plates of both culture media (30 plates of culture media containing 5 eggs each per treatment).

The egg sterilization methods also were evaluated by rearing 100 larvae that hatched from eggs treated with peracetic acid and 100 larvae from eggs treated with sodium hypochlorite. These larvae were reared on the WGCS

medium and the percentage of contaminated rearing containers, the average percentage of surface contamination, and the survival percentage to the pupal stage were compared between the treatments. Controls included 100 larvae hatched from untreated eggs and 100 rearing containers that held WGCS medium but no larvae. The brush used to transfer larvae to rearing containers was sterilized with Amphyl® disinfectant after every third transfer.

Samples of the constituents of the WGCS medium were plated on 10 replicate dishes of each culture medium to evaluate this source of contamination. To reduce contamination in the WGCS medium, its ingredients were treated in the following ways: (1) wheat germ was sterilized by autoclaving at 15 psi for 30 min prior to mixing the medium, termed AUTOWG; (2) 0.25% sorbic acid was added to AUTOWG as an additional mold inhibitor, termed AUTOWG+S; (3) the WGCS medium was autoclaved at 15 psi for 30 min, termed AUTOWGCS; (4) the wheat germ was sterilized over propylene oxide for 24 h prior to mixing the medium, termed FUMWG; (5) the wheat germ was sterilized with dry heat for 4 h at 180° C prior to mixing medium, termed DRYWG; and (6) the standard WGCS medium, termed CHECK.

The initial generation of *D. amatella* reared on each experimental medium was started with surface sterlized eggs collected from generations 27 through 34 of the laboratory colony. First-stage larvae were reared individually to the pupal stage in test tubes containing the experimental media. The number of days until first visual evidence of contaminated media, number of days to larval death, and duration of the larval stage were recorded.

Darkened pupae from each medium were held in individual 25 x 95 mm vials that contained a piece of 1 x 6 cm screen and were fitted with a cork stopper. The sex and weight of the pupae, and the duration of the pupal stage were recorded for each individual. Samples of moths that emerged on the same day from each experimental medium were transferred to wire screen cages (30 x 30 x 30 cm) for mating and egg deposition. The moths were provided water from a sponge held in an uncovered petri dish. The number of cages observed for each medium depended on the timing of moth emergence and the numbers of emerging moths. Egg deposition was recorded in an average of 4 cages (range 1 to 6) per replicate; the grand average was 14 cages (range 3 to 34) per treatment. The average number of moths per cage was 4.8 (range 2 to 10) and the average sex factor (ratio of females to total) was 0.4 (range 0.2 to 0.6) per cage. Each cage contained 2 cross sections (ca. 1.5 cm thick x 4 cm dia.) cut from fusiform rust galls of slash pine because host plant material was essential for mating and oviposition. Each cross section of gall was wrapped in 2 layers of cheesecloth upon which moths deposited eggs. The galls were replaced every 2 days with freshly cut cross sections and wrappers. The cheesecloth wrappers facilitated removal of eggs from the galls and supported the eggs during surface sterilization. Numbers of eggs deposited on the cheesecloths and numbers of larvae hatching from each batch of eggs were determined daily. The generation time was calculated by summing the average duration of development for female insects from egg to adult and the average preoviposition period.

Differences among treatment means were tested for statistical sig-

nificance by analysis of variance and Duncan's multiple range test, and are reported as means ± standard errors. Prior to these analyses, data collected as percentages were transformed to arc sin $\sqrt{\text{proportion}}$, but only the percentages are listed in the tables and results.

Results and Discussion

Behavior of Moths and Effects of Host Plant Material

A t-test for paired observations revealed no significant difference ($P > 0.01$) between diel periodicities of locomotor activity of male and female moths. Locomotor activity began at 1825 ± 0.5 (N=165) and ended at 0532 ±1.7, i.e., it began about 25 min after dark and continued until ca. 28 min prior to the onset of photophase. During each photophase, moths generally remained motionless unless disturbed. The pattern was similar to that reported for *D. ebeli* (Fatzinger 1973) and the presence or absence of a fusiform rust gall had no effect. However, *D. amatella* calling, mating, and oviposition did not occur in cages without fusiform rust galls (26 ♀ moths and 9 pairs of moths). In contrast, *D. ebeli* readily mated and oviposited in laboratory cages without host plant material (Ebel 1959, Merkel and Fatzinger 1966, Fatzinger 1970b).

When the females were 2 days old, calling behavior began ca. 8 h after dark and ended ca. 2.5 h later. Two- to 5-day-old virgin moths began to mate ca. 9 h after dark and ceased to mate ca. an hour later (Fig. 1). These ob-

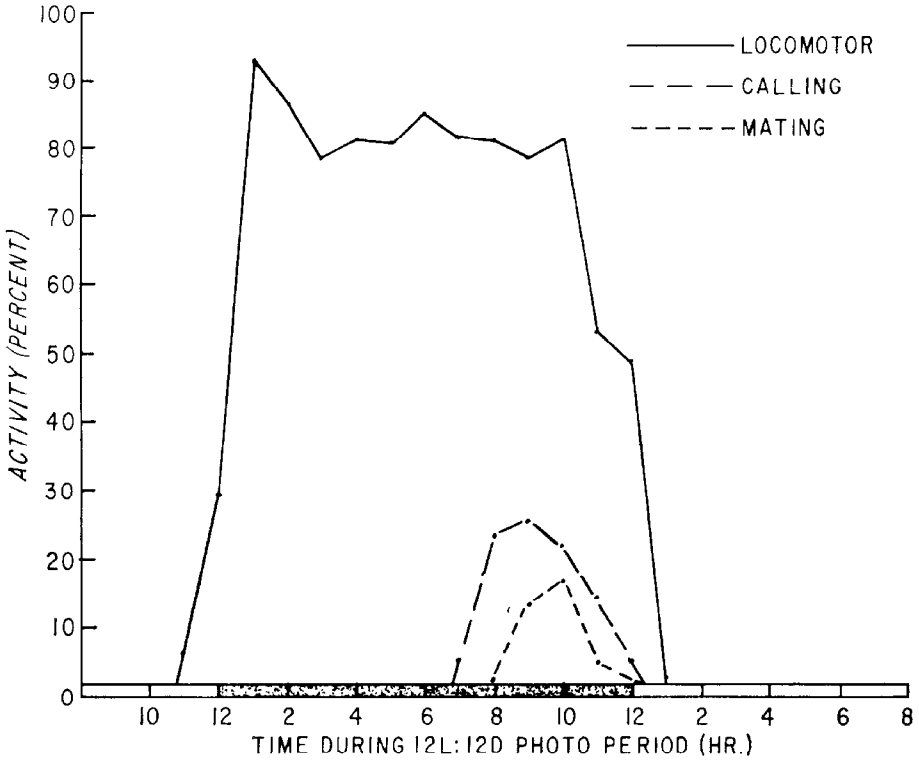

Fig. 1. Periodicity of locomotor, calling, and mating activity of *Dioryctria amatella*.

servations agree with the delayed mating reported by Ebel (1965). Multiple mating at intervals of 1 to 5 days was observed in both males and females; 3 ♀ and 2 ♂ mated twice and one pair mated 3 times.

Effect of Larval Rearing Density

During this study the same quantity of food was placed in each rearing container regardless of the number of larvae reared per container. The average numbers of pupae recovered per container from rearings at different larval densities were 0.58 ± 0.04 pupae at 1 larva container, 1.25 ± 0.14 pupae at 2 larvae/container, and 0.91 ± 0.10 pupae at 3 larvae/container. Survival of pupae was the same at all densities, averaging $83.1 \pm 1.6\%$, and the differences were due to larval mortality. Larval mortality at the highest density was significantly greater than at the 2 lower densities ($P<0.01$). Several partially eaten pupae were found, but cannibalism was rare.

Larval density did not significantly ($P>0.01$) influence the time required to rear larvae from the first stage through pupation. The average durations were 30.8 ± 1.0, 26.1 ± 1.8, and 28.1 ± 0.5 days for larvae reared 1, 2, or 3 per container, respectively.

Of the 9,494 rearing containers containing 3 larvae per container, ca. 5% were heavily contaminated (95% of the medium surface was contaminated). Only ca. 1% of the rearing containers with 1-2 larvae per container became heavily contaminated. The increased incidence of excessive contamination for colonies reared with 3 larvae per container was probably due to the greater chance of transferring larvae hatched from imperfectly disinfected eggs to a given container.

Dead larvae were found more frequently in excessively contaminated rearing containers. Prior to death, many of these larvae remained in the first or second stage while larvae in other containers progressed to the fourth or fifth larval stage. The physical barrier formed by microorganisms on the surface of the medium apparently caused the larvae to die from starvation (Fatzinger 1970b, Bucher and Bracken 1976).

Some larvae that hatched from eggs oviposited in the fall and winter remained in the first stage for as long as 66 days before dying (Fig. 2). They readily crawled about if disturbed but remained in the first stage long after the remainder of the colony pupated. In North Carolina, *D. amatella* overwinter primarily as early-stage larvae (Neunzig et al. 1964). In laboratory and field populations of *D. amatella* from north Florida, Ebel (1965) found early-stage larvae that ceased active feeding in the fall and winter, and either wandered about or remained inactive among cone scales or bark crevices. The inactive first-stage larvae observed during rearings may have been exhibiting the overwintering behavior of wild populations and they may have died from starvation because the medium deteriorated.

Surface Sterilization of Eggs

Eggs collected from the rearing cages were contaminated with both bacteria and fungi. Significantly fewer eggs were contaminated ($P<0.01$) after treatment with peracetic acid (33.7%) or sodium hypochorite (53.7%), but treatment with peracetic acid was superior. However, equal production of pupae was obtained from eggs surface-sterilized by either method (Table

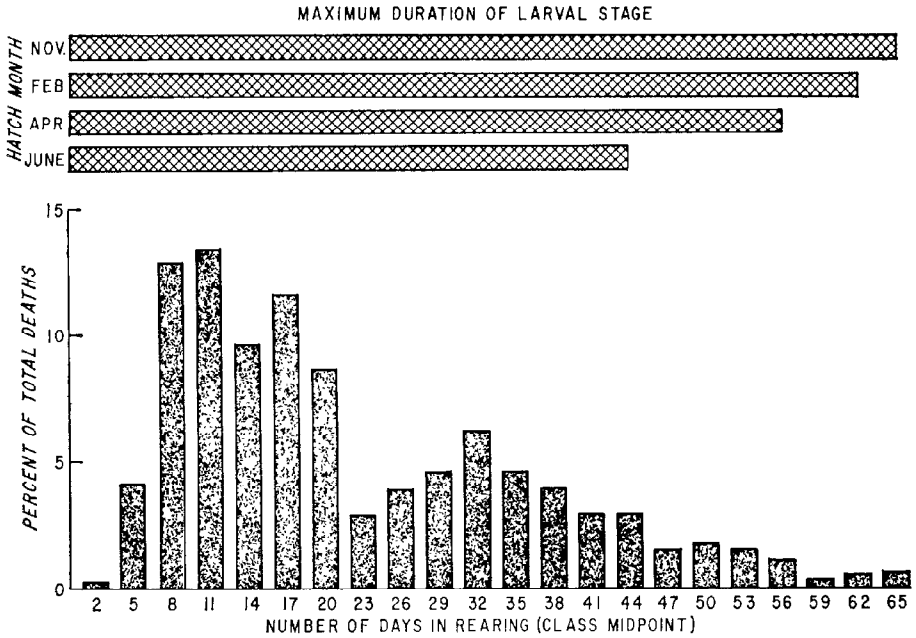

Fig. 2. Number of days *Dioryctria amatella* larvae lived after hatching during different months and life spans of those that died after being placed on artificial media.

1) and that production was higher than that from untreated eggs. Contamination of rearing containers held without larvae was minimal.

Decontamination of the Larval Rearing Medium

Wheat germ and casein were the primary sources of contaminants in the WGCS medium. All the plates containing wheat germ showed visible growth of microorganisms but only 25% of the plates containing casein showed

TABLE 1. Effect of surface sterilization of eggs on contamination of rearing containers and survival of *Dioryctria amatella* reared on the WGCS medium.

Treatment	Percent		
	Contaminated rearing containers*	Average surface area of medium contaminated**	Survival to pupal stage*
Peracetic acid	39	13.2 a	80
Sodium hypochlorite	55	19.6 a	82
Non-sterilized eggs	84	41.5 b	52
WGCS medium only	22	0.8 c	—

*A X^2 test for independence showed significant differences among treatments at the 1% probability level.

**Visually estimated to the nearest percent in contaminated rearing containers. Any 2 means followed by the same letter are not significantly different at the 1% probability level.

contaminants to be present. Therefore, the 5 modifications of the WGCS medium were designed primarily to decrease contamination originating from wheat germ. The elapsed time for visual evidence of surface contamination did not differ significantly among media (Table 2). There were some significant differences in percentages of rearing containers that became contaminated and in survival from the larval to the adult stages. The lowest incidence of contaminated rearing containers and the highest survival rate of larvae was associated with the AUTOWG+S medium. Although the AUTOWG+S medium was not significantly different from the AUTOWGCS, AUTOWG, or FUMWG media, it was the only medium tested that produced significantly more moths than the CHECK medium. Dry heat sterilization of wheat germ was the least effective method.

The type of medium did not significantly influence the duration of individual stages or the generation time which averaged 47.9±1.1 days (Table 2). The average weights of pupae, however, were significantly different among some of the media. The number of eggs deposited by individual females (average 95.4±12.6, N=176) and percentage hatch (47.5±3.4, N=16,725 eggs) were not significantly ($P>0.01$) affected by the media.

Conclusions

Moths of *D. amatella* were nocturnally active during 12L:12D photoperiods. Female calling behavior and subsequent mating and oviposition were dependent on the presence of host plant material. Mating behavior was delayed for 2 days after emergence and occurred during the last 5 h of scotophase. Multiple matings occurred, but were infrequent.

Survival of *D. amatella* larvae was optimized when 2 larvae were reared per 30 ml container and microbial contaminants were eliminated. Thus,

TABLE 2. Survival from first-stage larvae to adults, contamination of rearing containers, pupal weights, and generation times of *Dioryctria amatella*, reared on modified WGCS medium.*

Medium**	Average percent survival to adult stage	Contamination: % of rearing containers	Contamination: Avg. No. days to first visible growth	Pupal weight (mg)	Generation time (days)†
AUTOWG+S	83.5 a	3.0 a	17.2 a	94.7 a	48.5±4.4
AUTOWGCS	70.6 a b	21.7 a b	6.1 a	91.5 a	44.0±1.9
AUTOWG	61.6 a b	28.3 a b c	15.3 a	88.0 a	47.5±1.5
FUMWG	45.7 a b	43.7 a b c	10.4 a	86.7 a	50.8±3.2
CHECK	42.5 b	64.5 b c	15.2 a	77.2 b	50.8±3.3
DRYWG	28.5 b	81.5 c	12.7 a	79.8 b	48.7±9.9

*Any 2 means followed by the same letter are not significantly different at the 1% probability level by Duncan's multiple range test (N=150-652 larvae, 2-8 replicates).

**AUTOWG+S=Wheat germ autoclaved plus sorbic acid, AUTOWGS=entire medium autoclaved, AUTOWG=wheat germ autoclaved, FUMWG= wheat germ fumigated, DRYWG =wheat germ dry heat sterilized.

†$\bar{X} \pm t_{0.01} S_{\bar{X}}$

semiaseptic techniques should be used when preparing the medium and transferring larvae to rearing containers. Peracetic acid or sodium hypochlorite were equally effective for surface sterilizing eggs; however, sodium hypochlorite is less flammable, easier to store, and more readily available. Sorbic acid should be added to the medium and the wheat germ autoclaved.

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EFFECTS OF 'ANTIGUA 2D-118' RESISTANT CORN ON FALL ARMYWORM[1] FEEDING AND SURVIVAL[2,3]

B. R. WISEMAN, N. W. WIDSTROM, AND W. W. MCMILLIAN[4]

ABSTRACT

The impact of a fall armyworm resistant corn, 'Antigua 2D-118', on larval numbers was measured for 3 years in field studies. The susceptible standard, 'Cacahuacintle Crosses' (Cac.C) had ca. 2 times as many fall armyworms as did 'Antigua 2D-118' 10 days after infestation. The resistance of 'Antigua 2D-118' was expressed in fewer larvae per plant and less leaf damage than the susceptible entry for all 3 years.

RESUMEN

En un estudio de campo de 3 años se evaluaron el efecto sobre el número de larvas de una linea de maíz, 'Antigua 2D-118', la cual es resistente a *Heliothis zea* (Boddie). Diez días después de la infestación, el estandard susceptible, Cacahuacintle Crosses (Cac. C.) tenía cerca de doble el número de larvas que tenía Antigua 2D-112. En, cada uno de los 3 años, la resistencia de Antigua 2D-118 se medía en menos larvas por planta y menos daños a las hojas que en el estandard.

Plant resistance to insects has been reported as an ideal control method for insect pests (Luginbill 1969). Dahms (1972) showed the role of plant resistance in an integrated control program by demonstrating the direct and indirect effects of all 3 mechanisms of resistance (nonpreference, antibiosis, and tolerance) and he gave examples of how resistant varieties reduced insect populations. Schalk and Ratcliff (1976) reported an evaluation of programs of the Science and Education Administration (USDA) whereby the use of insect-resistant cultivars has been successful in controlling insect pests and in reducing the use of insecticides. Wiseman et al. (1978) found

[1]Lepidoptera: Noctuidae.

[2]In cooperation with the University of Georgia College of Agriculture Experiment Stations, Coastal Plain Station, Tifton, GA 31793. Accepted for publication 8 September 1981.

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that when corn earworms, *Heliothis zea* (Boddie), were placed on silks of resistant corn, only one-fourth as many emerged as compared to a susceptible corn.

Increased emphasis on fall armyworm, *Spodoptera frugiperda* (J. E. Smith), plant resistance research has occurred since the development of artificial infestation procedures (Wiseman and Davis 1979, Wiseman et al. 1980, Wiseman and Widstrom 1980). Germplasm resistant to the fall armyworm has been discovered (Wiseman et al. 1966, Wiseman et al. 1976, Davis et al. 1978). In a recent study, the nonpreference and antibiosis mechanisms of resistance were both found in selected resistant corn entries (Wiseman et al. 1981). This paper reports on a 3-year study of the effects of a resistant corn on fall armyworm numbers.

Materials and Methods

'Antigua 2D-118' and 'Cacahuacintle Crosses' (Cac.C), representing resistant (R) and susceptible (S), respectively, to fall armyworm leaf feeding, were planted on 10 April 1978, 9 April 1979, and 16 April 1980. Tests each year were arranged in a split-plot design for each of 10 replications. Whole plots (6.1 m rows 0.76 m apart) were days larvae were counted after initial infestation and subplots were the corn entries. Plants within treatments were infested at ca. the 10-leaf stage of plant development using the modified bazooka (Wiseman et al. 1980). First instars were dispensed in a mixture of corncob grits (#2040 grit-o'-cobs®) at the rate of 20 larvae/plant in 0.2 ml of grits. Larval counts were made on 10 individual plants at 6, 8, 10, and 12 days after infestation in 1978 and 4, 6, 8, and 10 days after infestation in 1979 and 1980. Damage ratings were made at 15 days after infestation using a visual damage rating scale of 0-9 where 0 = no damage and 9 = plant perishes. Analyses of the data were made for each year and Duncan's multiple range test was used to separate means.

Results and Discussion

For 2 of the 3 years, test numbers of fall armyworm larvae declined by at least 50% from initial infestation until 10-12 days after infestation (Table 1). Significant differences were found among means in 1978 for 6, 8,

TABLE 1. Combined mean numbers of fall armyworm larvae/plant at 4, 6, 8, 10, or 12 days after infestation. 1978-80.

Days after infestation	Mean number of larvae*		
	1978	1979	1980
4	—	8.3 a	13.0 a
6	2.4 a	6.7 b	9.0 b
8	1.6 b	6.4 b	6.9 c
10	1.2 c	4.4 c	4.5 d
12	1.0 c	—	—

* Means within a column for a given year followed by the same letter are not significantly different at P = 0.05. Combined means are averages of the number of larvae over both resistant and susceptible entries at days after infestation.

and 10 days after infestation; but no differences were detected between the mean number of larvae at 10 and 12 days after infestation. Since this was the case, larval numbers were counted beginning at 4 days past initial infestation in 1979-80 instead of 6 days. Thus, we could better understand the earlier effects of the resistant vs the susceptible on the fall armyworm. In both years, there was a significant decline in the number of larvae found at 6 days compared with 4 days. Generally, during the 1978 testing period, no rainfall occurred in and around the period of initial infestation. However, for both 1979 and 1980, rainfall occurred throughout the testing period. Rainfall occurring immediately following the initial infestation may be a contributory factor in the higher establishment in both 1979 and 1980 than in 1978.

The resistance of 'Antigua 2D-118' to the fall armyworm relative to 'Cac.C' was maintained throughout the testing years (Table 2), even though the number of larvae/plant was almost twice as much in 1980 for 'Antigua 2D-118' as compared to 1979. Damage ratings also supported the fact that 'Antigua 2D-118' maintained its resistance; it was significantly less damaged in all cases than 'Cac.C.'

The apparent differences in the ratios of larvae to plant damage ratings for 1978 and 1979-80 may be because initial larval counts were not made until the fourth day after infestation in 1978 and/or that rainfall during the periods of infestation for 1979-80 reduced adverse environmental influences, which permitted a higher larval establishment. Thus, more larvae were found at each recording period for 1979-80.

The effects of the 2 corn entries on fall armyworm numbers at 4, 6, 8, 10, or 12 days after initial infestation of 20 larvae/plant are shown in Table 3. In 1978, 'Antigua 2D-118' had significantly fewer larvae than 'Cac.C' at 6, 8, and 10 days after infestation, but not at 12 days, even though 'Cac.C' had almost twice as many larvae per plant (Table 3). Ratios of larvae per plant on the resistant vs the susceptible for 1978 were: 1:3.4 at 6 days, 1:3.0 at 8 days, 1:3.0 at 10 days, and 1:1.8 at 12 days for an overall ratio for 1978 of 1:2.9. In 1979-80, 'Antigua 2D-118' had significantly fewer larvae at every count as compared with 'Cac.C.' Ratios of larvae per plant on the resistant vs the susceptible for 1979 were: 1:1.9 at 4 days, 1:3.2 at 6 days, 1:3.4 at 8 days, and 1:3.4 at 10 days, with an overall ratio of 1:2.7 larvae for the resistant vs the susceptible. Ratios of larvae per plant for the resistant vs the susceptible for 1980 were: 1:1.3 at 4 days, 1:1.8 at 6 days, 1:1.9 at 8 days, and 1:1.8 at 10 days, with an overall ratio of 1:1.6. There-

TABLE 2. MEAN NUMBER OF FALL ARMYWORM LARVAE AND MEAN DAMAGE RATING FOR A RESISTANT 'ANTIGUA 2D-118' AND A SUSCEPTIBLE 'CAC.C.' 1978-80*.

Entry	No. larvae/plant			Mean damage rating		
	'78	'79	'80	'78	'79	'80
'Antigua 2D-118'	0.8 a	3.5 a	6.4 a	1.4 a	2.7 a	4.0 a
'Cac.C'	2.3 b	9.4 b	10.3 b	2.5 b	5.5 b	5.8 b

*Means within a column for a given year followed by the same letter are not significantly different at P = 0.05.

TABLE 3. EFFECTS OF A RESISTANT AND SUSCEPTIBLE CORN ON FALL ARMYWORM NUMBERS. 1978-80.

Days after infestation	Number of larvae/plant*								
	1978			1979			1980		
	A		C	A		C	A		C
4	—		—	5.8 a	*	10.8 a	11.3 a	*	14.7 a
6	1.1 a	*	3.7 a	3.2 b	*	10.1 b	6.4 b	*	11.6 b
8	0.8 a	*	2.4 b	2.9 b	*	9.8 b	4.7 bc	*	9.0 c
10	0.6 a	*	1.8 bc	2.0 c	*	6.8 c	3.2 c	*	5.7 d
12	0.7 a	n.s.	1.3 c	—		—	—		—

*Means within a column for a given year and entry followed by the same letter are not significantly different at P = 0.05. Horizontal means within a given year with * between the corn entries are significantly different at P = 0.05. A = resistant 'Antigua 2D-118' and C = susceptible 'Cac.C.'

fore, for the 3-yr testing period, 'Cac.C' had ca. twice as many fall armyworms per plant as 'Antigua 2D-118.'

Wiseman et al. (1981) found in laboratory tests that 'Antigua 2D-118' only had a slight level of antibiosis and that most of its resistance was due to the mechanism of larval nonpreference. Thus, the nonpreference type of resistance of 'Antigua 2D-118' can impact detrimentally on fall armyworm numbers.

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COMMUNITY COMPOSITION AND ZOOGEOGRAPHY OF THE INVERTEBRATE CAVE FAUNA OF BARBADOS

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Abstract

A survey of the macroscopic invertebrate fauna of Coles Cave, the largest undisturbed cave in Barbados, found a community of at least 44 non-accidental species. Most of the species are supported by scavenging on bat guano but at least 7 are predators and 1 is a parasitoid. The species richness is mostly terrestrial, for only 7 species were found in the aquatic stream community. Only a milliped seems to be cave-restricted, and few of the species are endemic to Barbados. Three have been introduced by man. The community shows little apparent niche separation and is generally composed of species that are normally forest litter-inhabitants. They mostly arrived at the island of Barbados by overwater dispersal since its emergence in the Pleistocene, and then moved to the cave habitat via the forest understory.

Resumen

La cueva de Cole es la mas grande sin molestar en la isla de Barbados. La cueva tiene una comunidad, por lo menos, de 44 especies que viven allí naturalmente. Algunos de las especies viven por comiendo la guano de los murcielagos, pero 7 son de rapiña y una es parásito. Lo mas de las especies son terrestre y 7 son acuático. Solamente un diplopodo aparece limitado a la cueva, y unas de las especies son endémico a Barbados. Hay tres que han introduicido por hombre. La comunidad generalmente esta formado de especies que normalmente viven en la tierra vegetal de bosques. Las especies han dispersado sobre el mar desde la isla surgió en la periodo Pleistoceno, y entonces pasaron a la cueva via la tierra vegetal.

Caves can serve as models for testing evolutionary, ecological and biogeographic hypotheses (Culver 1970, 1971; Culver et al. 1974; Vuilleumier 1973) but this has been attempted mostly for temperate zone caves. Data are not yet adequate for such analyses for tropical zone caves, although they are rapidly becoming available for the islands of the Caribbean (Peck 1974, 1975, 1977, 1981; Peck and Peck 1981; Orghidan et al. 1977; Taboada 1974).

This paper is offered as a data base on the invertebrate cave fauna of Barbados, in the Lesser Antilles, as a step towards the formation of generalizations on the distributional and ecological characteristics of Neo-

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tropical cave communities. It is part 8 in a series on the invertebrate fauna of tropical American caves.

BARBADOS. This is a relatively small island, 32 km long and 23 km across, with a maximum elevation of 370 m. It lies in the tropical Atlantic about 150 km east of the Windward Islands of the Lesser Antilles Island Arc (Fig. 1 inset). It has a sub-humid to humid maritime tropical climate. The island is situated on a north-south ridge of sediments uplifted at the eastern margin of the Caribbean plate as it overrides the Americas Plate. The island is unusual for the Lesser Antilles in that it is non-volcanic, and 6/7 of its area is mantled by a succession of concentric Pleistocene reef terraces. These have been isotope dated (Bender et al. 1973, Matthews 1973) and show a correlation of increasing age with elevation, as the island was uplifted. A conclusion is that land for overwater terrestrial biotic colonization has only been available since the early Pleistocene. This gives a valuable reference point in time by which to evaluate the dispersal and colonization potential of

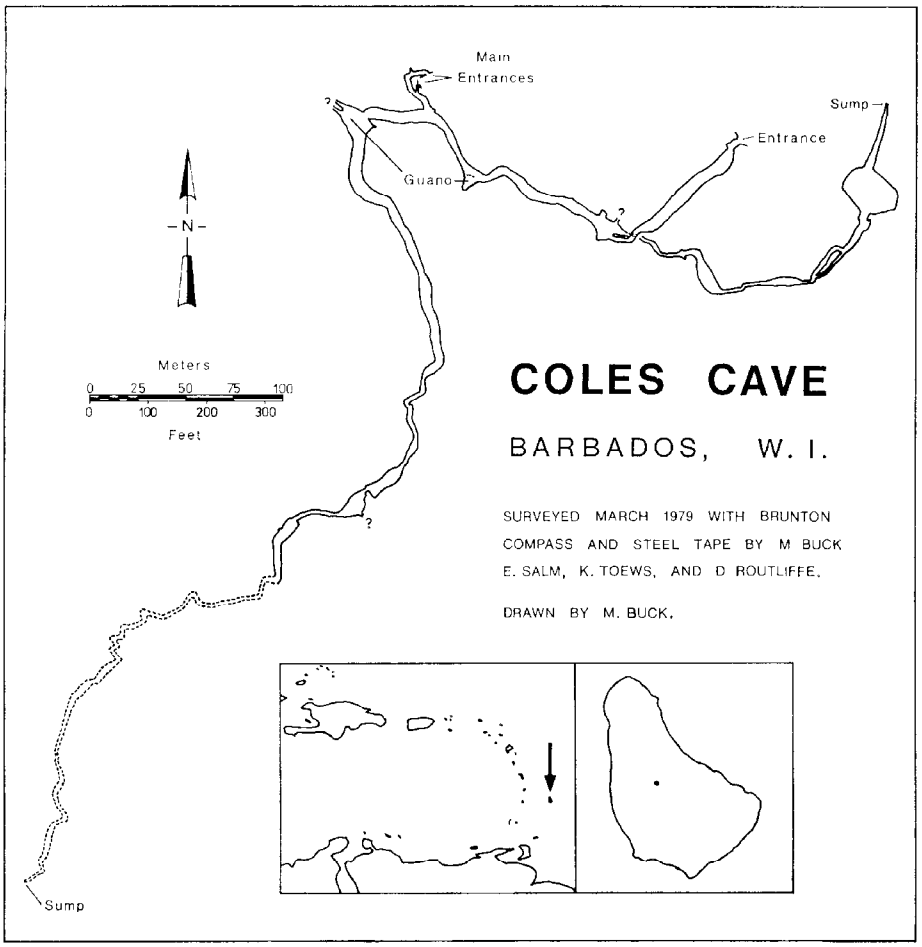

Fig. 1. Map of Coles Cave. Insets show position of Barbados (arrow) in the tropical Atlantic, east of the Lesser Antilles Island Arc, and the position of the cave on the island (dot).

different taxa (Peck and Peck 1980). These upraised reefs have been a site for studies of karst development (Fermor 1972, 1977).

CAVES. Many small caves exist in the loosely consolidated faces of inland and seaside coralline cliffs and gully walls, but few go into a zone of complete darkness. Animal Flower Cave, on the NE coast, is a sea cave tourist attraction with sea anemones. Several caves have been used as a water source by the Government Waterworks Department, such as Harrison Cave, Baker's Cave, and Cole's Cave. This is no longer true for Cole's Cave. Harrison Cave, near Welchman Hall, is now being developed as an attraction for the tourist industry.

Cole's Cave is the largest and least disturbed cave in Barbados. It is located in a gully bottom between Walkes Spring Plantation and Welchman Hall near the center of the island, grid coordinates F.4, 3.7, on the 1:50,000 Barbados Topographic Map. It is reached by a dirt road entering the sugar cane fields to the southwest, from a main road just south of Clifton Hill Chapel. When the field to the north ends because of the steep lip of the gully, a foot path goes down into the gully, and into the climb-down sink (swallow hole) entrance of the cave. The cave is at approximately 200 m elev., under the approximately 240 m high coral terrace of early or mid Pleistocene age.

The cave is essentially a medium diameter (walking) stream passage about 1000 m in length. The stream generally flows to the southwest, on coral rubble (Fig. 1). Two side chambers have large piles of guano produced by the bat *Brachyphylla cavernarum minor* Miller (Swanepoel and Genoways 1978). The cave was once gated to exclude bats because they were thought to be a health hazard. The upstream entrance is still closed against bats. The fauna was most abundant in the high and narrow tunnel descending from the main dome-pit entrances and at the guano. Fauna in the stream was only seen in guano-laden pools beneath the bat roosts. Carrion baits in the stream drew no crustacean fauna. The air and water temperature in the upstream half was 23°C and the air at the end of the smaller diameter downstream passage (which floods significantly) was 25°C.

The macroscopic fauna of Coles Cave was surveyed in 3 trips to the cave in February, 1979, while studying the forest litter invertebrates in Barbados (Peck and Peck 1980). No synthetic work on the terrestrial or freshwater invertebrate faunas is available for Barbados as it is for some other islands (Harrison and Rankin 1976). Subterranean groundwaters of Barbados were sampled for crustaceans in 1979 by Jan Stock, who found the interesting *Typhlatya* cave shrimp (pers. comm.), which will be reported elsewhere. The following list reports the trophic role of the species, and the level of cave restriction (troglophile indicates that the species can exist as reproducing populations in caves but is not limited to them). Information on the geographical distribution is given wherever possible.

ANNOTATED FAUNAL LIST

Phylum Plathyhelminthes
  Class Turbellaria
    Order Tricladida
      Family Planariidae

Dugesia sp. (?).[1] Guanophage. Troglophile. These 0.75 cm long flatworms were on submerged guano.

Order Alloeocoela

Undetermined family, genus, and species. Guanophage. Troglophile. Very small, pale, eyeless, oval flatworms were common on submerged guano.

Phylum Annelida

Class Oligochaeta

Order Haplotaxida

Family Enchytraeidae

Genus and species undetermined. Guanophage. Troglophile. Small pot-worms were abundant in soil and guano. The species are usually widespread.

Family Aeolosomatidae

Aeolosoma sp. Guanophage. Troglophile. Abundant on submerged guano. Worms in this genus are often found in highly polluted waters. The species are usually widespread.

Family Tubificidae

Tubifex sp. Guanophage. Troglophile. Abundant on submerged guano. Worms in this genus are often found in highly polluted waters. The species are usually widespread.

Phylum Mollusca

Class Gastropoda

Order Stylommatophora

Family Subulinidae

Subulina octona (Bruquiere). Guanophage. Troglophile. Only dead shells were found in the entrance passage. This very adaptable species is widespread through the world tropics and was probably spread through commerce. It is frequent in Caribbean caves.

Family Zonitidae

Retinella sp. (?). Guanophage. Troglophile. This low spired, pale, and thin shelled snail occurred at the edge of guano piles.

Order Basommatophora

Family Physidae

Physa sp. Guanophage. Troglophile. This genus of snail is also known from a guano ladden cave stream in Jamaica (Peck 1975).

Phylum Arthropoda

Class Crustacea

Order Oniscoidea

Family Oniscidae

Trichorhina tomentosa Budde-Lund (?). G. A. Schultz det. Guanophage. Troglophile. The specimens all seem to be females, and parthenogenesis is common in the genus. These were exceptionally abundant in guano. The species is reported from Venezuela, and the genus occurs elsewhere in the Antilles and South America.

Order Eucopepoda

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[1]The question marks indicate determinations that cannot be verified by a specialist for a variety of reasons.

Family Cyclopidae

Mesocyclops sp. (?). Guanophage. Troglophile. Copepods occasionally occur in guano-rich streams in caves in Puerto Rico and Jamaica. The species are usually widespread.

Class Arachnida

Order Aranea

Family Theridiidae

Euryopis sp. One immature female, W. A. Gertsch det. Predator. Troglophile.

Family Philodromidae

Genus and species undetermined. Three juveniles, W. A. Gertsch det. Predator. Troglophile.

Order Acarina

Family, genus, and species undetermined. Guanophages and predators. Troglophiles. This is probably a rich fauna, judging by the guano mite faunas known from Puerto Rico and Mona Island (32 and 17 species respectively).

Order Schizomida

Family Schizomidae

Schizomus spp. J. Reddell det. Predators. Troglophiles. Two undescribed species are represented by males and females. It is interesting that the widespread species, *S. puertoricensis* (Chamberlin), which is often found in Caribbean caves, is not present here (see Rowland and Reddell 1980).

Order Amblypygi

Family Phrynidae

Phrynus barbadensis (Pocock). Predator. Troglophile. This is also recorded from Trinidad. These are usually predators on crickets in caves. They are abundant in Neotropical lowland caves (Mullinex 1975).

Class Diplopoda

Order Polydesmida

Family Stylodesmidae

Undetermined genus and species. W. A. Shear det. Guanophage. Troglobite (?). This seemingly new and cave-limited genus and species was common on guano.

Order Spirobolida

Family Rhinocricidae

Eurhinocricus sp. W. A. Shear det. Guanophage. Troglophile. These very large millipeds were exceedingly common in the entrance tunnel, in the quano chambers, and elsewhere. The genus also occurs in Mexico and Central America.

Class Symphyla

Family Scutigerellidae

Scutigerella sp. Guanophage. Troglophile. Found in soil at edges of guano piles. These omnivores are generally soil inhabitants, and several species have been widely distributed by man.

Class Insecta

Order Collembola

Family Entomobryidae

Cyphoderus sp. K. Christiansen det. Guanophage. Troglophile.
Heteromurus sp. K. Christiansen det. Guanophage. Troglophile.
Family Sminthuridae
Dicyrtoma sp. K. Christiansen det. Guanophage. Troglophile.
Family Hypogastruridae
Brachystomella sp. K. Christiansen det. Guanophage. Troglophile. While collembola are frequent cave inhabitants, the above genera are not commonly encountered in Caribbean caves.
Order Thysanura
Family Nicoletiidae
Nicoletia sp. (?). Guanophage. Troglophile. All members of this family are blind scavengers of hypogean habitats. Some are known only from caves, but others have been spread by man.
Order Diplura
Family Campodeidae
Lepidocampa (*Lepidocampa*) sp. L. Ferguson det. Guanophage. Troglophile. These are frequent soil inhabitants, and species in this genus are widespread. This seems to be the first record from a cave.
Order Orthoptera
Family Gryllidae
Amphiacusta sp. Guanophage. Troglophile. The genus occurs on many Caribbean islands, and often forms large populations in caves.
Order Blattodea
Family Blattidae
Periplaneta americana (L.) Guanophage. Troglophile. This cosmopolitan species is native to tropical Africa, and is common in Caribbean guano caves.
Order Hemiptera
Family Cydnidae
Amnestus pusio (Stål). R. C. Froeschner det. Guanophage (?). Troglophile. The species is widespread in the tropical Americas. Members of the genus are frequent tropical cave inhabitants (Froeschner 1960).
Family Veliidae
Microvelia mimulus White. R. C. Froeschner det. Predator. Troglophile. These may prey on micro-crustaceans in (or collembola on) the water. They occur occasionally in tropical cave streams. The species is widespread through the West Indies, and Central and South America (Drake and Hussey 1955).
Order Lepidoptera
Family Tiniidae
Genus and species undetermined. Guanophage. Troglophile. Adults and larvae were in guano, which is a common habitat for them in the Neotropics.
Order Coleoptera
Family Hydrophilidae
Oosternum costatum Sharp. A. Smetana det. Guanophage. Troglophile. Abundant in guano. The species is widely distributed,

ranging from South America, through the West Indies and Central America, to the southeastern United States (Smetana 1978).

Family Staphylinidae

Aleocharinae, genera and species undetermined. Predators. Troglophiles. Two genera were present. These are frequent in guano, probably preying on mites.

Family Scarabaeidae

Ataenius luteomargo Chapin. H. F. Howden det. Guanophage. Accidental (?). The species is endemic to the Caribbean, being known from the 4 Greater and many of the Lesser Antilles (Cartwright and Chalumeau 1978).

Order Hymenoptera

Family Eucoilidae

Pseudodiranchis sp. C. Yoshimoto det. Parasitoid. Troglophile. These are parasitic on larvae and pupae of flies, undoubtedly those in the guano.

Family Formicidae

Gnamptogenys sp., (*striatula* complex). P. Ward det. Predator (?). Troglophile. This large, black ponerine is native to the Antilles.

Hypoponera sp. P. Ward det. Predator (?). Troglophile. The genus is known from other Caribbean caves.

Wasmannia auropunctata Wheeler. P. Ward det. Predator (?). Troglophile. This tiny ant is an introduced tramp species of African origin.

Myrmecinae, genus and species undetermined. Predator (?). Troglophile.

Order Diptera

Family Phoridae

Undetermined genus and species. Guanophages. Troglophiles. Four species were present in the guano. These are common cave scavengers.

Family Sphaeroceridae

Undetermined genus and species. Guanophage. Troglophile. Members of this family are commonly found in moist guano.

Discussion

At least 44 non-accidental species of invertebrates occupied Coles Cave. More will be added if determinations become available on the mites. The species are mostly guanophages and are supported directly by their feeding on the abundant food source of bat guano. The diversity is mostly in the terrestrial environment (only 7 species are aquatic but more microscopic protistans are probably present). Predaceous species are 2 spiders, 2 schizomids, the amplypygid, 2 staphylinid beetles, the *Microvelia* bug and probably some mites and ants. One parasitoid is present. The *Subulina* snail, *Periplaneta* roach, and *Wasmannia* ant were introduced by man. Few of the species seem to be endemic to Barbados.

Only the stylodesmid milliped appears to be a cave-evolved species. All others are troglophilic species with broad ecological tolerances and requirements. This is a loosely structured community, where few species interact

with each other directly, and there is little apparent niche separation. The prime interaction is seemingly directly between the guanophages and their food resource. The richness of the community is interesting; to join it most species had to pass or overcome 2 dispersal barriers or filters. The first and most important was in reaching the island itself, probably mainly from South America and (for a litter fauna) via rafting in debris of the Orinoco River, though direct observations seem not to be available. The second was in locating the specific habitat of the cave. No published data are available on the occurrence or abundance of the invertebrate species in other habitats in Barbados, but there seems to be little reason to think that they do not occur elsewhere. It is probable, following the extensive clearing of Barbados for sugar cane plantations by 1700, that many of the forest litter species are now much less abundant.

Analysis of the freshwater invertebrate faunas of nearby (150 km to the west) St. Vincent by Harrison and Rankin (1976) suggested that these faunas are remnants (following a vicariance breakup or fragmentation) of a richer ancestral land mass and biota (Rosen 1975). While this may be so for St. Vincent (and other islands in the Lesser Antilles arc) the geological story of Barbados, as now understood, seems to require initial overwater colonization by all its biota in or since the Pleistocene.

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VELVETBEAN CATERPILLAR[1]: RESPONSE OF MALES TO VIRGIN FEMALES AND PHEROMONE IN THE LABORATORY AND FIELD

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ABSTRACT

Observations of the sexual behavior of *Anticarsia gemmatalis* (Hübner) were made in the laboratory and field during 1976. The calling behavior of the female is characteristic of many moth species in that the tip of the abdomen is curved upward when calling. In the laboratory, males fly in a zig-zag path toward calling females or to pheromone extracts. Clasper extension by some males was observed as they approached the pheromone source. Females began calling ca. 2 h after sunset and this behavior continued intermittently throughout the scotophase. Mating and increased age greatly reduced the attractiveness of females to males in field traps. Pheromone was obtained from both non-calling and calling females. In field bioassays, extracts from females collected before and after dark were effective in attracting males, with extracts taken at 4 and 6 h after dark capturing the most males. Seven trap designs were evaluated for effectiveness at capturing *A. gemmatalis* males, but only the electric grid trap proved efficient and warranted further use.

RESUMEN

El comportamiento sexual de *Anticarsia gemmatalis* (Hubner) fue observado en el campo y en el laboratorio en 1976. El comportamiento de la hembra en atraer a los machos es semejante a el de muchas otras especies de polillas, eso es, el punto del abdomen se encuerva para arriba. En el laboratorio los machos vuelen en un rumbo de zigzag hacía las hembras atractantes y hacía extractos de feromanos. Se observaron la extensión de los agarradores de unos machos cuando estos acercaron el fuente de la feromona. Las hembras empezaron a "llamar" (atraer machos) cerca de 2 horas despues de la puesta del sol y este comportamiento siguía intermitentamente durante el período de oscuridad. El apareamiento y la edad avanzada reducen mucho la actractividad de las hembras en trampas. Se obtuvieron la feromona de hembras que llamaba y los que no llamaba. En bio-ensayos de campo, los extractos de las hembras que se capturaron antes y despues del período de oscuridad fueron efectivos en atraer a los machos. Los extractos de las hembras capturadas 4 y 6 h despues de volverse oscuro atrayeron el máximo número de machos. Se evaluaron 7 diseños de trampas por efectividad en capturar machos de *A. gemmatalis*. Solamente la trampa de rejilla eléctrica resultó bastante eficiente para continuar usarlo.

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Greene et al. (1973) made observations in field cages on mating and oviposition behavior of the velvetbean caterpillar, *Anticarsia gemmatalis* (Hübner). They suggested the existence of a female sex pheromone, after noting that males frequently would fly around females whose abdomen tips were pointed dorsally. Because insect sex pheromones are providing new methods of controlling insect pests, we initiated investigations to confirm the presence of a sex pheromone in *A. gemmatalis* and to identify parameters which may affect female attractiveness and male response.

Procedures and Results

Insects used in these experiments were reared on an artificial diet according to the methods of Greene et al. (1976). Insects were sexed in the pupal stage (Butt and Cantu 1962) and placed in pans of moist vermiculite. Males and females were allowed to eclose in screenwire cages in separate rooms. Adults were maintained on 10% sucrose solution. Cages containing moths to be used in behavioral observations were held in greenhouse rooms which allowed penetration of sunlight (temperature ca. 24°C, RH ca. 55%). Female moths which were extracted for pheromone were held in a screenwire cage (63cm x 61cm x 91cm), under a light cycle of 12:12, photophase: scotophase (temperature ca. 24°C, RH ca. 55%).

Behavioral Observations: Observations of pheromone release behavior were made in the greenhouse room containing the males. Individual virgin females were confined in screenwire cylinders (4.5 cm, diameter x 12.7 cm, length) suspended within a larger cage (57 cm x 54 cm x 184 cm) containing ca. 100 virgin males. Observations of the calling behavior and the subsequent responses of males were made between 1730 and 0200 h on 7 consecutive nights. Sunset occurred at about 1800 h during these tests.

Males became active ca. 45 min. after sunset. This activity was characterized by apparently indiscriminate flight around the cage, followed by walking on the sides of the cage, and rapid fluttering of the wings. Females exhibited similar behavior except they were unable to fly because of their confinement. Obvious sexual activity was not noted until ca. 2 hours after dark. Female calling consisted of wing fanning followed immediately by dorsal elevation of the abdomen tip. Females repeated the calling behaviors in an unbroken sequence for a time period varying between a few seconds to several minutes. These calling sequences were repeated by each female several times during the observation period. Calling was observed only when females were on the vertical walls of the cage. During this activity, males flew toward calling females. Walking or non-calling females did not elicit male attraction.

Male response consisted of flying a zig-zag path toward the female. Flight was initially erratic but became more direct as the male approached the female. Upon reaching the female, the male flew around her several times, and either landed or flew away. As males hovered near the female, the claspers were usually extended.

Extraction of Pheromone: Calling females were vacuumed into a 1-liter jar containing sufficient ether to just cover the insects. The jar was checked often to insure that the females were always covered with solvent. Then they were extracted by soaking for 30 min. and the insect carcasses

were removed by filtration. The collection vessel was carefully rinsed twice with small portions of ether. This wash was added to the original filtrate by pouring it through the filtration apparatus (Mitchell et al. 1974). The excess ether was removed by distillation under atmospheric pressure through a 375 mm Vigreux column. This concentrated extract and the distillate were stored at —60°C until bioassay. The number of females obtained during each collection varied due primarily to the availability of insects. On various occasions, as few as 5 and as many as 75 females were collected. Collection required a minimum ca. 25 ml of solvent and the volume of residue after distillation was ca. 1 to 2 ml for each 100 insects extracted.

A bioassay of the concentrated materials was conducted by placing 25 female equivalents (FE) on a 9 cm Whatman #1 filter paper and presenting the paper to caged males. The cage and conditions were the same as those employed while making behavioral observations. The bioassay began at 2 h past sunset and the cage contained ca. 100 males. Using this procedure, ether extracts from calling and non-calling females collected at night were shown to be attractive and male responses were typical of the behavior shown by males approaching calling females.

FIELD BIOASSAYS: Traps of 7 different designs were tested to determine the most effective trap for capturing males: an electric grid trap (Mitchell et al. 1972); a double-cone trap similar to that of Kaae and Shorey (1972); an omnidirectional trap designed for pink bollworms, *Pectinophora gossypiella* (Saunders) (Sharma et al. 1973); a screenwire trap used for the tobacco hornworm, *Manduca sexta* (L.) (Mitchell et al. 1972); a sticky trap used for the sugarcane borer, *Diatraea saccharalis* (Fabr.) (Perez and Long 1964); a Pherocon 1C sticky trap (Zoecon Corp., Palo Alto, CA); and a large walk-in trap constructed from screenwire used for capturing the lesser peachtree borer, *Synanthedon pictipes* (Grote and Robinson) (Gentry and Blythe 1978). Traps were baited with 3 virgin females (2- to 3-days old) and placed ca. 30 m apart in a soybean field near Gainesville, FL. Captured males were removed daily and the traps were rotated one position. Each collection was considered a replicate (4 replicates). Results obtained in this test indicated that the electric grid was the only trap effective against the VBC. The electric grid trap captured 5.9 ± 0.1 ($\bar{X} \pm$ S.E.) moths/trap/night. All other traps captured no VBC moths. The ineffectiveness of traps other than the electric grid for capturing fall armyworm, *Spodoptera frugiperda* (J. E. Smith), and the beet armyworm, *S. exigua* (Hübner), was noted by Tingle and Mitchell (1975). Therefore, all other field assays were conducted using electric grid traps.

The relative attractiveness of laboratory-reared and feral females was studied to insure that laboratory-reared females would provide reliable information. Individual feral and laboratory-reared females of equivalent age were placed in electric grid traps. The mean capture of males/trap/night by traps baited with feral females was 6.6 ± 1.3 and 4.6 ± 0.5 ($\bar{X} \pm$ S.E.) by traps baited with laboratory-reared females (15 replications, 3 traps/female type, for 5 consecutive nights). The mean capture by feral and laboratory-reared females was not significantly different (t-test, $t=0.407$). Unbaited traps captured no males.

The influence of age of females on pheromone production was evaluated in 2 tests. One test utilized 3 laboratory-reared females as bait. Age groups

tested were 1, . . .7 days post eclosion. A replicate was considered to be the capture of males by one trap/night (3 replicates/age group). The 2nd test utilized baits consisting of 20 FE of crude extract obtained from non-calling laboratory-reared females of different ages. Females were collected 2 hours after dark. Each age was replicated 4 times. All females used in these tests were aged in screenwire cages in the greenhouse. A pan containing female pupae was placed in a cage and allowed to remain over night. The following day the pan containing uneclosed pupae was transferred to a second cage leaving the newly eclosed females behind. Therefore, each cage contained females which had eclosed during a single night.

In the tests using live females, the baits were placed in the field just before sunset and removed the following morning. Test females were held during the day at 15°C under a photoperiod approximating that in the field. Females dying during the day were replaced with females of equivalent age. Pheromone extracts were tested by placing 20 FE in 0.25 ml of solvent on a 9 cm #1 Whatman filter paper and suspending it within the trap. Trap location within the field was constant. At each collection, the treatment was replaced with a new and different one; these treatments were rotated throughout the field. Moth capture for the extracts were recorded hourly (replicate). Extracts for each age group (1, 2, 3, 5, 10 days old) were replicated 4 times. Tests were run between 2400 and 0300 h.

In tests using live females 1-7 days of age as baits, trap capture of males was 45 ± 19, 66 ± 12, 37.3 ± 9, 43.3 ± 21, 11.3 ± 4, 10.6 ± 4, and 5 ± 1, respectively ($\bar{X} \pm$ S.E.). Linear regression analysis substantiated a decrease of male capture with increasing age of the bait females ($P = .05$). In tests using 20 FE of crude extract obtained from 1, 2, 3, 4 and 10-day-old females capture of males was 3 ± 1.6, 2.5 ± 0.2, 2.3 ± 1, 3.5 ± 3 and 3.0 ± 0.6, respectively ($\bar{X} \pm$ S.E.). No significant difference in attractiveness of these baits to VBC males was apparent. This was somewhat surprising in that there was a significant decline in the number of VBC males captured in traps baited with live females of different ages. Thus, one might assume that not only age but age in conjunction with exposure to the changing environment caused the decrease in female attractiveness. The extracts were taken from females which were not exposed to these changes as they were held under constant temperature, humidity, light cycle and food supply.

The nocturnal sexual activity of the VBC male was monitored with an electric grid trap equipped with an automatic sample-changing device (Mitchell et al. 1972) that captured males and segregated samples into hourly intervals. The trap was baited with 3 laboratory-reared females. The bait females were placed in the trap ca. 1 h before sunset (20:15 EDT) and removed early the following morning. Captured male VBC were counted daily. Each night's capture was considered a replicate (8 replicates). Captures of VBC males commenced ca. 1 h after sunset and remained fairly uniform throughout the night ($\bar{X} \pm$ S.E. captures/h $= 4.4 \pm 0.8$).

Female VBC were extracted with ether as described previously to determine if the pheromone could be obtained at any time during the photoperiodic cycle. Laboratory-reared females held under a 12:12 photophase: scotophase were collected at 9 and 6 h before dark, immediately after the lights were turned off and 2, 4, 6 and 9 h into the scotophase. Females were extracted when ca. 3 days old. The extracts were bioassayed between 2400

and 0300 h by baiting individual electric grid traps with 20 FE of pheromone in 0.25 ml of solvent on a 9 cm #1 Whatman filter paper. Counts of captured VBC males were recorded hourly (replicate), and the filter paper was replaced with fresh bait. Each treatment was replicated 4 times. All treatments attracted some wild VBC males (2.5, 2.0, 2.0, 0.7, 5.6, 4.6 and 1.5 $\bar{X}$ males/treatment, respectively). However, significantly more males were attracted to pheromone extracts obtained from females 4 and 6 h into the scotophase ($P=0.05$, Duncans Multiple Range Test).

The effect of mating on female attractiveness to wild males was determined by comparing the capture of males by traps baited with mated females to that of virgin females of equivalent age. Newly emerged virgin laboratory-reared females were placed in 4 liter paper cartons with virgin laboratory-reared males at a ratio of 1 female to 4 males. The carton tops were replaced with screenwire and the insects were held for 2 nights in the greenhouse under natural light. The following day, mated and virgin females were placed in traps ca. 1 h before sunset, and they were removed early the following morning. Each trap contained 1 female. Four traps per female type per night for 8 nights were used in this evaluation. Male captures were recorded daily (replicate). Females were dissected to confirm mating. The mean capture of males in traps baited with virgin females was 16.8 ± 0.6 ($\bar{X} \pm$ S.E.) as compared to 1.5 ± 0.8 ($\bar{X} \pm$ S.E.) males captured in traps baited with mated females (means differ significantly at the 1% level, student's *t*-test). The reduction in attractiveness of mated VBC females to feral VBC males is consistent with results reported for other moth species (Perez and Long 1964, Raulston et al. 1975).

This investigation has confirmed the presence of a female-produced sex pheromone in *A. gemmatalis*. The pheromone can be extracted with ether yielding an attractive extract to both laboratory-reared and wild males when tested under both laboratory and field conditions.

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SCIENTIFIC NOTES

MULTIPARASITISM OF PUSS CATERPILLAR BY A WASP AND FLY SPECIES (LEPIDOPTERA: MEGALOPYGIDAE)—(*Note*). Multiparasitism is parasitism of one host individual by 2 or more different species of parasites. The megalopygid moth, *Megalopyge opercularis* (J. E. Smith), is parasitized in the cocoon stage by the ichneumonid, *Lanugo retentor* (Brulle), and in the larval stage by one of 2 tachinid flies, either *Carcelia lagoae* (Townsend) or *Euphorocera* sp. The tachinid flies glue their eggs on the exterior of larvae. On hatching they become endoparasites. The wasp *L. retentor*, on the other hand, oviposits only after the formation of the cocoon and its larva lives as an ectoparasite on the host prepupa within the shell of the cocoon (Khalaf 1975. Loyola Univ. Press, New Orleans, Louisiana. 43 p.).

Experimental multiparasitism was induced following collection of mature puss caterpillars (*M. opercularis*) at various times of the year from oak trees in the streets of New Orleans. These were intended to serve as hosts for the rearing and colonization of *L. retentor*. Many collected caterpillars already harbored one of the tachinid parasites. Caterpillars lived in the laboratory on oak leaves or artificial diet and in a few days formed cocoons. A few days later, the cocoons were exposed to female *L. retentor* and then were incubated for observation or for later dissection. Wasps were secured from numerous cocoons, undoubtedly some after participating in unsuspected multiparasitism. On the other hand, test cocoons from which flies emerged following exposure to wasp oviposition represented known multiparasitism and are listed in Table 1.

In case #1 pupation of the flies occurred after host cocoon formation; thus the pupal stage of the fly was less than one month at that time of the year. In case #2, the tachinid flies that emerged were sluggish and died within 2 days. In case 5, the wasp penetrated the cocoon but removed the ovipositor quickly, signifying that an egg was not laid. The wasp then penetrated again and even tried to penetrate for the third time when it was finally removed. I repeatedly observed that when old host cocoons (e.g., 16 days old) containing one or more fly puparia were involved the penetrating wasp (even in cases of multiple penetrations) would withdraw the ovipositor quickly without laying an egg; *Carcelia lagoae* or *Euphorocera* sp. later emerged.

Multiparasitism was sometimes detrimental to both parasites (cases 7, 10, 12). In case 10, there was a scar on the puparium that could have been caused by the wasp larva or the wasp penetrations.

Host cocoons 8-21 were penetrated twice by the wasp at various intervals. The wasp accomplished the first oviposition readily since the tachinid larvae were still within the host. However, the behavior in the second oviposition, unless it followed the first in less than 3 days, was quite modified. Sometimes even at the 3 day interval, the second oviposition involved 1 or 2 short penetrations with a quick withdrawal (cases 15, 18); similar behavior was encountered in the 5 day interval (case 16). In the 6 day interval, wasp behavior involved rejection, prolonged or repeated short penetrations, and resting in contact with the cocoon between penetrations. Three or 4 days after the first oviposition, the fast feeding wasp larva seemed to

drive the tachinid larvae out of the host to form puparia. Tachinid puparia in host cocoons modified the wasp behavior, and rarely invited actual oviposition. Exceptions to this were cases 13 and 20 where the wasp laid an egg even after the 6 day interval.

Cases 20 and 21 shed some light on the nature of competition between the 2 parasites. The wasp larva apparently consumed the pupating fly, leaving only the outer cuticle. Therefore, this case of multiparasitism became hyperparasitism.

Another method was used to study multiparasitism; live, overwintering host cocoons were dissected on the day of collection between the first of February and the last part of March. Some of the cocoons were multiparasitized by both the wasp and a tachinid fly. Some live, overwintering host cocoons contained a large, living *Lanugo* larva in its own cell, and among the walled off material, the host larval skin was found with one or more tachinid egg shells still attached to it. In cases of numerous eggs, the tachinid species would most probably be *Carcelia* since a host parasitized by this species gives rise to many flies. There was no trace of live tachinids within the multiparasitized cocoons, nor was there a sign of tachinid emergence, indicating that the fly failed to develop, most probably because the fly parasitism came late in the life of the host larva. The presence of tachinid eggs on the prepupa was evidence that the tachinid eggs were sometimes laid on the integument of the last larval instar. On the other hand, the presence of live wasp larvae in the multiparasitized cocoons (with dead tachinid remains) does not necessarily indicate the wasp's success. Success necessitates at least the emergence of the wasp. For this reason cocoons from which the adult wasp emerged were dissected in search for tachinid eggs which might be attached to the host integument. Six of 41 host cocoons that overwintered and produced wasps also contained tachinid eggs.

In the final series of investigations, obviously parasitized cocoons from the field were dissected in a search for remains of the other parasitic species. The wasp leaves the host cocoon by chewing a hole; the tachinid flies leave by opening the operculum. Over 100 field-collected, deserted host cocoons were dissected. Evidence of tachinid parasitism was detected in 2 percent of the cocoons from which wasps emerged. Seven percent of cocoons from which flies emerged showed traces of unsuccessful wasp infection. (This investigation received support from the Academic Grant Fund of Loyola University.)—K. T. KHALAF; Loyola University, New Orleans, LA 70118 USA.

TABLE 1. RESULTS OF *Lanugo*—TACHINID—*Megalopyge* MULTIPARASITISM.

Case no.	Date of cocoon formation	Date of *Lanugo* oviposition	Parasite emerged	Date of emergence	Date and results of dissection of deserted host cocoon
1	X-5	X-12	7 *C. lagoae*	XI-2	—
2	X-5	X-12	15 *C. lagoae*	XI-7	a dead, young *Lanugo* larva.
3	VII-3	VII-5	1 *Euphorocera* sp.	VIII-5	—
4	VII-3	VII-5	1 *Euphorocera* sp.	IX-5	—
5	X-6	XI-1	8 *C. lagoae*	IV-13	—
6	Field multiparasitism		3 *C. lagoae*	I	dead, young *Lanugo* larva, a dead puparium and a dead fly larva.
7	Field multiparasitism		—	—	(Jan.) 4 dead tachinid puparia and a dead *Lanugo* larva (3.5 mm long).
8	VIII-29	IX-10-11	1 *C. lagoae*	IX-20	
9	X	Repeated			(Nov.) 4 tachinid egg shells attached to host, a live puparium, and 4 dead, small *Lanugo*, larvae.
10	IX-29	X-4-5	—	—	(March) a dead tachinid fly and a dead but grown *Lanugo* larva.
11	VI-29	VII-4 & -10	♂ *L. retentor*	IX-14	walled off was a dead adult *Euphorocera* sp. halfway emerged from puparium.
12*	—	X-4 & -10	—	—	a dead tachinid fly and a dead *Lanugo* larva.
13*	—	VII-4 & -10	2 *C. lagoae*	—	one *Carcelia* larva did not leave host, became black, perhaps injured. 2 dead *Lanugo* larvae, one grown and one tiny.
14*	—	VII-5 & -8	4 *C. lagoae*	VII-25	collapsed *Lanugo* egg.

TABLE 1. CONTINUED

Case no.	Date of cocoon formation	Date of *Lanugo* oviposition	Parasite emerged	Date of emergence	Date and results of dissection of deserted host cocoon
15*	—	VII-5 & -8	8 *C. lagoae*	VII-27	a dead, tiny larva and a collapsed, embryonated *Lanugo* egg.
16*	—	VII-6 & -11	3 *C. lagoae*	VII-25	—
17*	—	VII-11-12	♂ *L. retentor*	IX-11	3 tachinid puparia walled off.
18*	—	VII-5 & -8	5 *C. lagoae*	VII-24	—
19*	—	VII-5 & -7	6 *C. lagoae*	VII-26	—
20*	—	VII-10 & -16	4 *C. lagoae*	VIII-1	a dead, brown tachinid larva, a dying 5 mm *Lanugo* larva and another dead, tiny *Lanugo* larva.
21*	—	VII-12 & -17	1 *C. lagoae*	VIII-3	another dead, brown fly larva failed to form puparium, with scars and sucked dry. Underdeveloped *Lanugo* larva spun flimsy cocoon, and another dead *Lanugo* larva.

* The first penetration of cocoons 12-21 was usually ca. 4 days after cocoon formation.

CITRUS PULP BAIT INSECTICIDE FORMULATIONS FOR CONTROL OF VELVETBEAN CATERPILLAR[1] AND BEAN LEAF BEETLE[2] ON SOYBEAN[3]—(*Note*). Ground citrus pulp has recently been developed as a carrier for technical methomyl under the trade name Nu-bait R[4] which contains 1.25% AI by weight. Martin (1979. Insecticide and Acaricide Tests 4: 126-7) and Bass (1979. Insecticide and Acaricide Tests 4: 142-3) reported control of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), on Coastal bermudagrass and peanuts, respectively, with this product. The same material was considered as a potential carrier to enhance activity of microbial insecticides. To investigate this possibility, Dipel^R, a commercial formulation of *Bacillus thuringiensis*, was formulated by blending with ground citrus pulp at a ratio of 1:19 wt/wt. The test described here was conducted to determine the activity of both formulations against the velvetbean caterpillar (VBC), *Anticarsia gemmatalis* Hübner, the bean leaf beetle (BLB), *Cerotoma trifurcata* (Forster), and non-target arthropods on soybeans.

A small-plot field trial was initiated on soybeans on 3 October 1979, at the Black Belt Substation (Auburn University Agricultural Experiment Station) near Marion Junction, Alabama. An infestation of VBC (34.2 larvae/row m) was found which was uniformly distributed over a small, late-planted field of 'Bragg' variety soybeans in the R6 developmental stage (Fehr, W. R. and C. E. Caviness. 1977. Iowa Coop. Ext. Serv. Rep. 80: 12 p.). Significant numbers of BLB (22.4 adults/row m) were also present at this date.

Treatments used in the test included Nu-bait at rates of 0.14 and 0.28 kg AI/ha, ground citrus pulp containing 0.56 kg Dipel/ha, methomyl (Lannate 1.8EC) spray at 0.50 kg AI/ha, and an untreated control. A completely randomized field plot design was utilized with 2 replications. Replication number was limited by the small field size and minimal plot size required. Plots were 4 rows (0.91-m spacing) by 15.2 m. Bait formulations were applied with a cyclone-type, hand-operated applicator (Seymour No. 75 Universal Spreader) calibrated to deliver 11.2 kg of bait/ha. Plots receiving 22.4 kg of bait/ha were treated twice at the 11.2 kg delivery rate. Methomyl was applied with a CO_2 sprayer calibrated to deliver 187 l total volume/ha with 3 nozzles (TX 4 cone spray tips) at 2.11 kg/cm^2 (30 p.s.i.).

Target pests were sampled by the shake-cloth technique (Boyer, W. P. 1963. Coop. Econ. Insect Rep. 13: 91-2). Three 0.91 row-m samples were taken at 2 and 5 days post-treatment in each plot. Larval counts were taken in small and medium plus large size classes so that total VBC counts and counts of the damaging size classes (medium plus large) could be analyzed separately. In addition, the effects on non-target insects were measured by taking 9.1 row-m D-vac samples (Dietrick et al. 1959. J. Econ. Ent. 52: 1085-91) in each plot on each sample date. Insects collected in the latter samples were returned to the laboratory and sorted into various taxonomic categories. All insect counts from both sampling techniques were analyzed by analysis of variance and means were compared by multiple range tests.

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[1]*Anticarsia gemmatalis* Hubner (Lepidoptora: Noctuidae).
[2]*Cerotoma trifurcata* (Forster) (Coleoptera: Chrysomelidae).
[3]Alabama Agricultural Experiment Station Journal Series #15-81007.
[4]A product of Griffin Corporation, Valdosta, Georgia.

Populations of both VBC and BLB increased in untreated plots in the 2 days between treatment and first evaluation. Increase in VBC could be attributed to a large egg hatch, since the majority were small larvae at 2 days post-treatment. Increase in BLB numbers may be related to movement from immediately adjacent soybeans which were senescing rapidly.

Nu-bait at both 0.14- and 0.28-kg rates significantly reduced VBC populations at 2 days post-treatment (Table 1). At 5 days, the reduction was still evident. Methomyl, utilized as a standard control and applied at 0.50 kg, significantly reduced VBC populations by 93 and 88% at days 2 and 5, respectively, but provided no better reduction of VBC numbers than citrus pulp containing only 1/4 or 1/2 as much methomyl. Citrus pulp containing 1 kg of Dipel per 20 kg of formulation and applied at the rate of 11.2 kg of formulation or 8.9 billion international units of potency/ha reduced VBC levels by 50 and 100% at days 2 and 5, respectively. The slower mode of action necessitates a 5-day reading for this material. All size classes of VBC were effectively reduced by all treatments, although percent reductions of small larvae were generally somewhat higher than reductions of medium + large larvae.

BLB populations were affected in several different ways by the various treatments. Both Nu-bait treatments significantly reduced BLB populations at 2 days, while methomyl spray did not (Table 2). Dipel applied in citrus pulp was ineffective against BLB. At day 2, plots treated with Dipel in citrus pulp actually had significantly higher (by 50%) BLB populations than in untreated plots. Dipel applied as a spray in a separate test (Harper, J. D. 1981. Insecticide and Acaricide Tests 6: 147) also was shown to have no activity against BLB. These results suggest that the citrus pulp attracts BLB. By day 5, all treatments had similar BLB populations, suggesting that BLB is highly mobile and that the effects of the bait on it are rapidly masked in small plots by interplot movement. For this reason, large plots would be

TABLE 1. COUNTS OF VELVETBEAN CATERPILLARS, *Anticarsia gemmatalis* HÜBNER, FOLLOWING TREATMENT ON 3 OCTOBER 1979, WITH SELECTED INSECTICIDES—MARION JUNCTION, ALABAMA.*

Material	Rate (kg AI/ha)	Pre-treatment	Days post-treatment			
			2		5	
			Med. & large larvae	Total larvae	Med. & large larvae	Total larvae
Untreated	—	34.2	46.5a	102.3a	31.7a	78.7a
Nu-Bait	0.14	—	10.4c	17.0b	1.6b	1.6b
Nu-Bait	0.28	—	8.7c	9.3b	8.7b	15.9b
methomyl	0.50	—	2.7c	7.7b	4.4b	9.3b
citrus pulp + Dipel	0.56**	—	27.3b	50.9b	0.0b	0.0b

*Numbers within columns followed by the same letter are not significantly different (DMRT) at the 0.05 level.
**Expressed as kg of Dipel/ha.

TABLE 2. COUNTS OF BEAN LEAF BEETLES, *Cerotoma trifurcata* (FORSTER), PER ROW-M OF SOYBEANS FOLLOWING TREATMENT ON 3 OCTOBER 1979, WITH SELECTED INSECTICIDES—MARION JUNCTION, ALABAMA.*

Material	Rate (kg AI/ha)	Pre-treatment	Days post-treatment	
			2	5
Untreated	—	22.4	61.8b	48.7a
Nu-Bait	0.14	—	24.6cd	39.4a
Nu-Bait	0.28	—	12.6d	33.4a
methomyl	0.50	—	47.6bc	54.7a
citrus pulp + Dipel	0.56**	—	93.0a	37.7a

*Numbers within columns followed by the same letter are not significantly different (DMRT) at the 0.05 level.
**Expressed as Kg of Dipel/ha.

needed to determine efficacy of the methomyl baits on BLB representative of operational conditions.

Non-target arthropods were separated into 18 different taxonomic categories ranging from order to species. Individual taxa were generally present in small numbers in the D-vac samples. Populations of most individual taxa present showed no significant response to any treatment at either day 2 or 5 post-treatment. Total numbers of non-target arthropods were highest (but not significantly) in the Dipel bait plots on both dates (Table 3). This apparent concentration of organisms, which included significantly higher numbers of predatory nabid nymphs (Hemiptera: Nabidae) suggests that the bait is acting as an attractant. Higher mortality in the pest species studied suggests that it may also be functioning as a gustatory stimulant. The exact nature of citrus pulp attractancy and its role in pest management should be explored further.—JAMES D. HARPER, Dept. Zoology-Entomology; Auburn University Agricultural Experiment Station; Auburn University, AL 36849 USA.

TABLE 3. NUMBERS OF ARTHROPODS OTHER THAN BEAN LEAF BEETLES, *Cerotoma trifurcata* (FOSTER) AND VELVETBEAN CATERPILLAR, *Anticarsia gemmatalis* HÜBNER, COLLECTED IN D-VAC SAMPLES FROM SOYBEAN PLOTS FOLLOWING TREATMENT ON 3 OCTOBER 1979, WITH SELECTED INSECTICIDES AT MARION JUNCTION, ALABAMA. ALL FIGURES ARE AVERAGE COUNTS PER 3 ROW-M OF BEANS.*

Day post-treatment	Treatment				
	Control	Nu-Bait (0.14 kg AI/ha)	Nu-Bait (0.28 kg AI/ha)	Citrus pulp + Dipel	Methomyl
2	38.0	35.0	28.0	62.0	21.0
5	11.5	15.0	16.5	26.5	18.5

*No significant differences occurred between treatments within dates (DMRT, 0.05).

"LOVE BITES" IN A LYCID BEETLE[1]—(*Note*). While copulating and mate-guarding, male insects are sometimes dislodged from their mounts by sexual rivals. Various clamps, claspers, spines, and gin-traps occur in the genital region to grip the female and secure the male's position (Parker 1970, Biol. Rev. 45: 525-67). But the lycid beetle *Calopteran discrepans* (Newn.), forms an unusual sexual attachment. Coupled males pierce the female integument with their mandibles.

In a deciduous forest in Alachua Co., Florida, I watched 40 male and 4 female *C. discrepans*. Males were engaged in short 0.1 to 3.0 m flights among the shrubs and herbs. After alighting they would flick open their large black and yellow poster-like elytra. In 45 landings the number of wing flicks varied from 0 to 13, with a mean of 1.3. Flicks may be an advertisement to females or an aposematic display to tracking predators (Burke 1976, Ent. News 87: 229-32; females also flick when disturbed and female *C. terminale* appear to flick more regularly than do males; again Burke (1976). Females were found in the leaf litter. The highly biased sex ratio, 10:1, suggests that males remain in emergence areas to search for mates.

Males mount dorsally, between the females' slightly spread wings. Examination of coupled pairs showed the sickle-like male mandibles bite through the humeral angle (shoulder) of the female's right elytron. Up to 3 males were found upon a female's back. When such masses were picked up, they clung together and were separated only with some effort, leaving bleeding wounds in the female's elytra. Interloping males inserted their jaws into the mid regions of the elytra. These positions are similar to those of the Nigerian lycid *Metriorrhynchus semiflabellatus* Thoms., in which a copulating male was seen to grip the right tibia of his mate and competing males held the edge and corrugations of the female elytra in their mandibles (Poulton 1913, Proc. Roy. Ent. Soc. [in trans.] LXXVIII). Burke (ibid.) found a non-mating *C. terminalis* male puncturing the intersegmental membranes between a female's metathorax and first abdominal segment. He presumed the male to be feeding on her body fluids and does not mention bites by copulating males, though a mating male had his head pressed against the same region of his mate. When disturbed, mounted *C. discrepans* raise their meso- and metathoracic legs, presumably to prevent the positioning of an interloper (much like the leg lifts of another cantheroid, the firefly *Photuris hebes* (= SH), Lloyd 1977, Florida Ent. 60:63).

Single males engage in biting combats. In one case, a captive male pierced the ventral thorax of his opponent and held him for 24 hours. A victory this expensive in time seems Pyrrhic. It is questionable whether fights in nature are so prolonged (more energetic and mortal use of mandibles occurs in the related phengodids, e.g. Tiemann 1967, Proc. California Acad. Sci. 35: 235-64).

Love bites, with their potential damage to the female, illuminate the different reproductive interests of the sexes. The diminished reproductive value of an injured mate can be offset by the greater percent fertilization a male achieves if his ejaculate is not mixed with a rival's. Thanks to D. Wojcik for supplying references.—JOHN SIVINSKI, Dept. of Entomology and Nematology, University of Florida, Gainesville, FL 32611 USA.

[1] Florida Agricultural Experiment Station Journal Series No. 0000.

WEST INDIAN RECORD FOR *ELASMUS POLISTIS* BURKS (HYMENOPTERA: EULOPHIDAE)—(*Note*). *Elasmus polistis*, a parasitoid of *Polistes* spp., was described by Burks (1971. J. Washington Acad. Sci. 61: 194-6) from specimens collected in Georgia, Maryland and Pennsylvania. Burks suggested that the species had been introduced, but had no clue as to its origin. Support of the introduction hypothesis is derived from the absence of *E. polistis* from several studies of *Polistes* nests prior to 1971 and its subsequent appearance as a common species in Pennsylvania, Maryland, Georgia, Texas and Oklahoma (Reed and Vinson 1979. J. Kansas Ent. Soc. 52: 247-57).

Specimens determined as *E. polistis* by NFJ were reared from nests of *Polistes crinitus* Felton by MAI at Charlotte Amalie, St. Thomas, Virgin Islands, on 15 June 1979; and from Estate Bordeaux, St. Thomas, VI on 25 November 1979. The Charlotte Amalie population showed a high incidence of parasitism; several thousand parasitoids were reared from a 2 liter container-full of nests. This is the first report of *Elasmus polistis* from outside the eastern and central U.S.A. and from the endemic West Indian *Polistes crinitus*.

Since *E. polistis* is probably an effective colonizer, its occurrence in the West Indies may be the result of another introduction. However, the infrequency of this type of collecting in the West Indies may have allowed its presence to go unrecorded. *Polistes* spp. are common here, and rearing attempts should be made on other islands. Additional distribution records may indicate a West Indian origin of this species.

Voucher specimens of *Elasmus polistis* from St. Thomas are deposited in the collection of the Ohio State University.—NORMAN F. JOHNSON AND MICHAEL A. IVIE, Department of Entomology, 1735 Neil Ave., Ohio State University, Columbus, OH 43210, USA.

BUFFALOGRASS, A NEW HOST FOR THE FALSE SPIDER MITE, *AEGYPTOBIA NOMUS* (ACARINA: TENUIPALPIDAE)[1]—(*Note*). Buffalograss, *Buchloe dactyloides* (Nutt.) Engelm. (Poaceae), is a prominent component of the shortgrass prairies of the American Southwest. Occasionally, buffalograss is used as a low-maintenance turfgrass in Southwestern lawns. The only previously reported pests are the buffalograss webworm, *Surattha indentella* Kearfott, in Kansas (Sorensen, K. A., and H. E. Thompson. 1979. J. Kansas Ent. Soc. 52: 282-96) and the white grub of *Phyllophaga crinita* Burmeister in Texas (Reinhard, H. J. 1940. J. Econ. Ent. 33: 572-8).

Aegyptobia (*Pentamerismus*) *nomus* (Baker and Pritchard) previously has been taken on *Bouteloa* (sic.) (=*Boutęloua*) *gracilis* (H.B.K.) Griffiths (Poaceae) (blue grama), in Mandan, North Dakota (15 Oct. 1920) and in Modena, Utah (22 Sept. 1925). It was also taken on *Distichlis stricta* (Torr.) Rybd. (Poaceae) (inland saltgrass) in Manden, North Dakota (15 Oct. 1920) (Baker, E. W., and A. E. Pritchard. 1953. Wasmann J. Biol. 11: 353-66).

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On 30 July and 25 August 1980, we found *A. nomus* infesting buffalograss at 2 sites in Dallas, Dallas County, Texas. A record drought and heat wave had forced unirrigated grasses into semi-dormancy, consequently leaf color was not a useful character for damage detection. What brought the infestation to our attention was the presence of "witches'-broom" fascicles produced by the abortion of internodes on some terminals. Microscopic examination of such terminals disclosed populations of *A. nomus* under the leaf sheaths.

Because *A. nomus* rarely is collected, it may have only minor pest potential on buffalograss. The apparent damage we witnessed may have resulted primarily from the unusual weather of the summer of 1980. Conversely, because buffalograss historically has been subjected only occasionally to cultivation, past infestations by this mite may merely have passed unnoticed.

We thank Dr. Edward W. Baker (USDA, SEA, Systematic Entomology Laboratory, Beltsville, MD) and the Florida Department of Agriculture's Division of Plant Industry for the taxonomic determination of *A. nomus*.—ROBERT L. CROCKER, WILLIAM E. KNOOP, AND JOHN M. OWENS, Texas A&M University Research and Extension Center, 17360 Coit Road, Dallas, Texas 75252 USA.

TOXICITY OF ATMOSPHERIC GASES TO IMMATURE STAGES OF *ANASTREPHA SUSPENSA*—(*Note*). Fumigation is one of the most effective ways of destroying insects, and development of new and improved techniques is a principal research effort at our station. The toxicity of atmospheric gases in high concentration has been known to entomologists for a long time. Carbon dioxide (CO_2) in particular was used almost routinely to anesthetize insects (to facilitate handling) until detrimental effects were detected (Sherman. 1953. J. Econ. Ent. 46:15-9). Controlled atmospheres (CA) are used during storage to prolong shelf-life of many fruits and vegetables (Hatton et al. 1975. Proc. Florida State Hort. Soc. 88: 335-8). The lethal effects on insects plus beneficial effects on commodities stimulated our interest in investigating the possibilities for controlling Caribbean fruit fly with atmospheric gases.

Immature stages of the Caribbean fruit fly were exposed for various periods of time to atmospheres of ethylene (C_2H_4), nitrogen (N_2), and carbon dioxide (CO_2). Gases were delivered in constant flow through wide-mouthed glass jars (2 liter) that served as CA chambers. Jars were connected in continuous series for each type or concentration of gas, and could be removed individually as needed to accommodate the time factor. Ethylene was mixed with air to a mean concentration of 940 ppm; N_2 and CO_2 were used pure (100%) or mixed with air to provide 40, 60, and 80% CO_2. All of the gases were humidified (90+% RH) by bubbling through water and were then passed at constant flow rates (2 liters/hr for C_2H_4 and 4 liters/hr for N_2 and CO_2) through the CA jars. Gas concentrations were measured by gas chromatography before and after entering the CA jars. The technique utilized a flame ionization detector for C_2H_4, and a thermal conductivity detector with appropriate columns for separating CO_2, O_2 and N_2. A small pump was used to pull air through the control jars at the same flow rates

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as those used for test gases. All tests were conducted at 22-23°C., except the egg test which was at 10°C. Mortality data in the treated lots were corrected for natural mortality in the controls (air flow) by Abbott's formula.

Mature Larvae. Naked Caribbean fruit fly larvae in lots of 200 were exposed to C_2H_4, CO_2, and N_2 for 4 to 7 hrs. Larvae were blotted dry (to prevent escape from containers) and placed in open petri dishes which in turn were placed in closed CA jars through which the gases flowed. Survivors were insects which were able to reach the adult stage. Ethylene at 940 ppm for 4 hr did not kill any larvae; CO_2 at 50% for 4 hr and 100% for 7 hr produced only 6.0 and 6.9% mortality, respectively; N_2 at 100% for 7 hr killed 7.4% of the larvae. A much longer exposure period would be required to produce a significant lethal effect from these gases. The poor performance by C_2H_4 coupled with the fact that it is explosive at 3% in air caused us to drop it from further consideration.

Pupae. Atmospheres of 100% N_2 and 100% CO_2 for periods ranging from 36 to 72 hr were tested against 4 and 11-day-old pupae to measure their ability to survive without oxygen. Pupae were exposed to the gases in lots of 200, and adult flies which were recovered following treatment were counted as survivors. Mortality of 4-day-old pupae ranged from 0 to 21% in N_2 and 0 to 3% in CO_2. For 11-day-old pupae the corresponding values were 0 to 17% in N_2 and 11 to 78% in CO_2. Nitrogen had similar but slight effect on both age groups, but CO_2 was uniformly more toxic to the older pupae.

Larvae in Artificial Diet. Five-day-old larvae were transferred (by artist's brush) in lots of 150 from the laboratory culture into 3.5 x 6 cm. dia. teflon-lined aluminum cups containing 40 ml of fresh laboratory diet. The cups were then placed into the 2-liter testing jars and exposed to 100% N_2 and 40, 60, 80, and 100% CO_2 for periods ranging from 36 to 96 hr. Larvae which attained full growth following treatment were counted as survivors. Sixty hours of exposure were required to kill all larvae in 100% N_2. Although there was not a clear correlation between CO_2 concentration and time of exposure, generally high mortality (95-100%) occurred at 48 hr with little added efficiency from longer exposures.

Eggs (1-day-old). Eggs from laboratory reared flies were delivered volumetrically by pipette (about 250 per drop) into cups containing 40 ml of fresh laboratory diet. They were then exposed to 40, 60, and 80% CO_2 for 48, 72, and 96 hr. Eggs hatch within 3 days at room temperature. We therefore conducted these tests at 10° C. to slow embryonic development and insure that only the egg stage would be treated. Larvae which hatched and were able to attain full growth were counted as survivors. Results were similar to those for young larvae, with near total kill (95-99%) at 48 hr exposure.

The toxicity of CO_2 to eggs and young larvae, in particular, indicates its potential for controlling this insect. Lethal effects of CO_2 were not clearly proportional to concentration, suggesting that there may be no advantage to increasing gas concentrations above a threshold level. Although CO_2 is slower acting than conventional fumigants, its activity appears to fall within the realm of practical application.—C. A. BENSCHOTER, D. H. SPALDING, AND W. F. REEDER, Subtropical Horticulture Research Unit, ARS-S&E-USDA, 13601 Old Cutler Road, Miami, FL 33158 USA.

MELILOTUS ALBA: A NEW HOST OF THE VELVETBEAN CATERPILLAR—(*Note*). Velvetbean caterpillar, *Anticarsia gemmatalis* (Hübner) (Lepidoptera: Noctuidae) larvae were first found on *Melilotus alba* Desr. near Homestead, FL on 5 March 1980. A total of 29 larvae were collected from this new host during March and April, 1980. Subsequently, larvae were collected from *M. alba* during May, 1981. *Melilotus alba* is a shrubby glabrous annual herb up to 2 m high and is found in wastelands and margins of cultivated fields throughout the US and southern Canada (Long and Lakela, 1971. A Flora of Tropical Florida. Univ. Miami Press). It has lush growth during February-May in southern Florida and may play an important role in the development of a migratory *A. gemmatalis* population.

This research was funded in part by EPA grant No. CR-806277-02-0, entitled "Development of Comprehensive, Unified, Economically, and Environmentally Sound Systems of Integrated Pest Management for Management for Major Corps". Florida Agricultural Experiment Stations Journal Series No. 3252. —VAN WADDILL, University of Florida, AREC, 18905 SW 280 St., Homestead, FL 33031 USA.

TENDING OF DEAD QUEENS BY WORKERS OF *SOLENOPSIS INVICTA* BUREN (HYMENOPTERA: FORMICIDAE)—(*Note*). As part of our normal research activity, we rear and maintain several hundred colonies of *Solenopsis invicta* Buren, the red imported fire ant. If the mother queen or her workers die they are normally discarded on the refuse pile within a few days. However, recently, while conducting laboratory tests with chemicals for toxic baits, we noted that worker ants from some colonies tended their queen for many weeks after she had been killed by exposure to the bait toxicant AC 217300 (tetrahydro-5,5-dimethyl-2(1H)[pyrimidinone (3-[4-(trifluoramethyl)phenyl]1(2-[-(trifluoromethyl)phenyl]ethenyl)-2-propenylidene)hydrazone). This compound was reported (Williams et al. 1980. J. Econ. Ent. 73: 798-802.) to be selectively toxic to the queen and that in large colonies the queen died within 2 to 4 wks even though thousands of workers survived exposure to the chemical. The queens of these colonies were physogastric and ovipositing at the time of exposure to the bait. In 13 of these colonies the surviving workers maintained the gaster of the queen for 3 to 9 weeks (Fig. 1), but in 4 others the workers quickly discarded the queen. The workers were also observed with the entire queen or the thorax and gaster, but they never maintained only the head or thorax alone or the head and thorax together.

The behavior of workers to the dead queen's gaster was typical of that observed with live queens, i.e., they clustered around the corpse with almost constant grooming and licking of the cuticle. With one exception, efforts to induce the workers to accept a new queen (2 to 4 wks old) were futile as long as they kept the dead queen. New queens were killed just as they would have been if a healthy queen had been present. However, once the body of the dead queen was discarded, a new queen was usually accepted. In 1978 two of our coworkers (A. Glover and B. M. Glancey, personal communica-

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The behavior of workers to the dead queen's gaster was typical of that observed with live queens, i.e., they clustered around the corpse with almost constant grooming and licking of the cuticle. With one exception, efforts to induce the workers to accept a new queen (2 to 4 wks old) were futile as long as they kept the dead queen. New queens were killed just as they would have been if a healthy queen had been present. However, once the body of the dead queen was discarded, a new queen was usually accepted. In 1978 two of our coworkers (A. Glover and B. M. Glancey, personal communica-

Fig. 1. Abdomen of dead queen of *S. invicta* tended by worker ants.

tion) also observed a colony of *S. invicta* that maintained the gaster of their dead queen for 7-8 months at which time ca. 100 workers remained alive. Several attempts to re-queen this colony resulted in execution of the new queen.

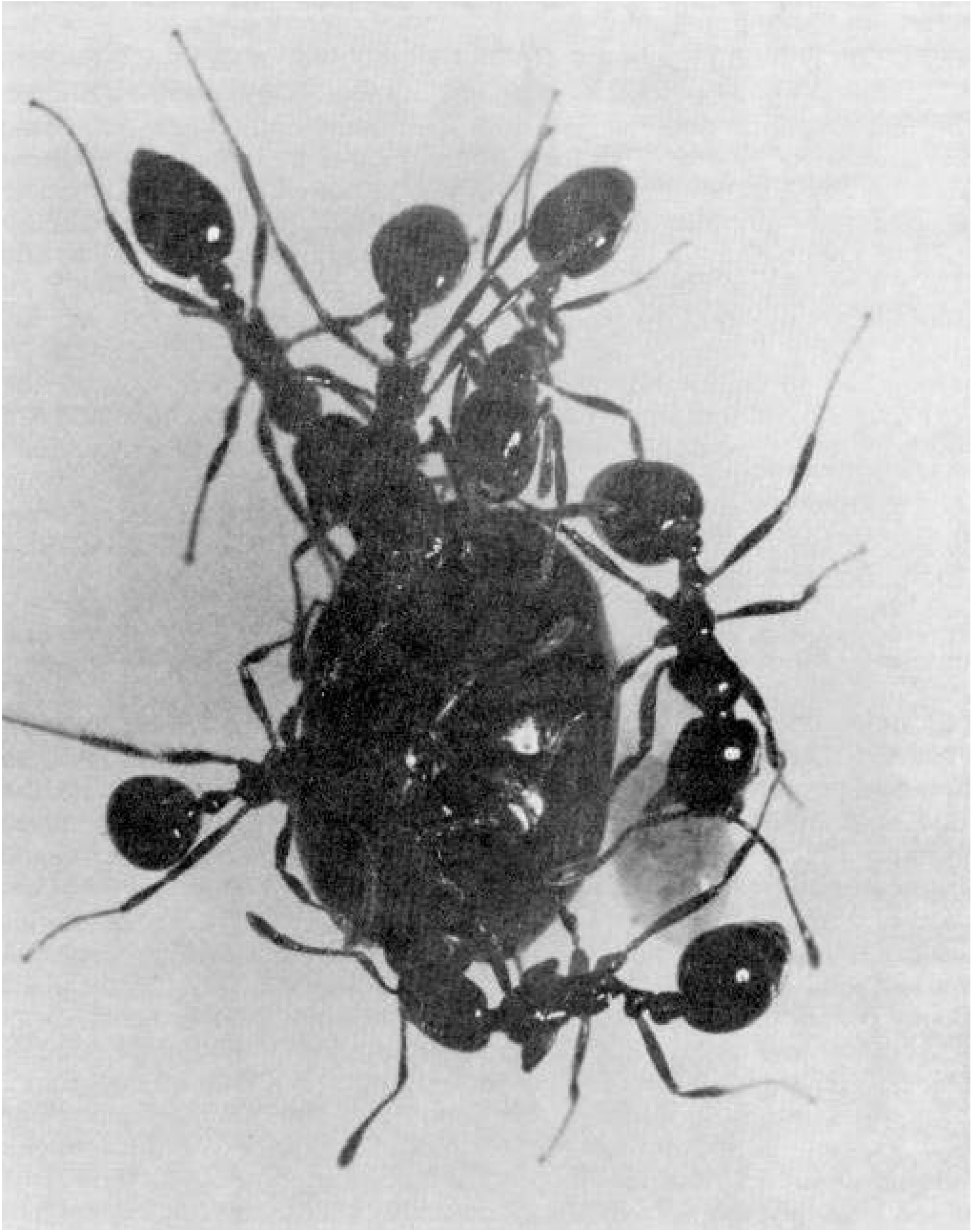
The observation of Glover and Glancey suggested that the tending behavior we observed was not related to some property of the toxicant, but rather to the physiological condition of the queen at the time of death. This hypothesis was strengthened when we killed 4 previously healthy queens by freezing. One queen was discarded after 8 days, another after 14 days. The 2

remaining queens were still being maintained at 15 days when they were removed for other tests.

Tending of dead queens by daughter worker ants for long periods of time (many weeks) has not been reported previously. Recently, Fletcher and Blum (1981. J. Georgia Ent. Soc. 16(3): 352-6.) reported on the use of dead queens of *S. invicta* as bioassay units to assay for the presence of a dealation inhibitory pheromone in mated queens. The length of time the dead queens were maintained during these studies was not specified. E. O. Wilson (1958. Psyche 65: 41-51.) noted that queens and some large major workers of *Pogonomyrmex badius* Latreille were kept within the nest under laboratory conditions for 3 days after death during which time they were licked and moved about. After this time, they were moved to the refuse pile. T. C. Schnierla (Army Ants: A Study in Social Organization, 1971.) while observing a trail of *Eciton hamatum*, found the headless body of a dead queen within a tight little ball of workers. Because of her dismembered and dried condition, he assumed that she had been dead for many days. Workers clung to the body when he moved it with tweezers.

Our observations suggest that the gaster-tending behavior is mediated by a pheromone produced by the queen while she is alive, but which remains on the cuticle or in some other organ or tissue after death. Jouvenaz et al. (1974. Ann. Ent. Soc. America 67: 442-4.) and Glancey (1978. Proc. Tall Timbers Res. Sta., No. 7, 173 p.) have reported that *S. invicta* queens produce a pheromone that attracts workers and Vander Meer et al. (1980. Ann. Ent. Soc. America 73: 609-12.) have shown that a queen-tending pheromone(s) can be extracted from the poison sac. The behavior induced by this pheromone is similar to that toward dead queens and can be mimicked with surrogate queens (small pieces of rubber septa) treated with extracts of the poison sac. The variability in retention time of the dead queen could be related to the condition of the poison sac after death. If it remains intact, the pheromone could be released slowly over a period of many weeks. Since the venom alkaloids possess antimicrobia activity, they could delay deterioration of the poison sac. On the other hand, decreases in pheromone production related to aging or senility or accidential destruction of the poison sac at the time of, or shortly after death, could account for early rejection of the dead queen.

The tending of dead queens by worker ants could be significant in planning control programs with bait-toxicants such as Amdro® because requeening of field colonies from mating flights by newly-mated queens may not occur as rapidly as expected. Thus, fewer treatments would be required to maintain control. Mention of a commercial or proprietary product in this paper does not constitute an endorsement or recommendation of this product by the USDA.—DAVID F. WILLIAMS, CLIFFORD S. LOFGREN AND ROBERT K. VANDER MEER, Insects Affecting Man and Animals Research Laboratory, ARS, USDA, P.O. Box 14565, Gainesville, FL 32604 USA.



The American Mosquito Control Association will hold its annual Photo Salon in connection with the annual meetings in Sacramento, California, 18-22 April 1982. There will be a Photographic Society of America-approved Insect Photo Salon and an AMCA Mosquito Photo Salon (which will cover all aspects of mosquitoes and mosquito control). Both salons will be conducted according to PSA standards. A silver medal will be awarded for "Best of Show" in each salon. The competition will be open to all photographers. The entry fee will be $3.00 and the closing date for receipt of entries will be 29 March 1982. Entry forms and complete details can be obtained from: JOHN T. BARBER, Chairman, AMCA Photo Salon, Biology Department, Tulane University, New Orleans, Louisiana 70118.

THE 65TH ANNUAL MEETING OF THE FLORIDA ENTOMOLOGICAL SOCIETY FIRST ANNOUNCEMENT AND CALL FOR PAPERS

The Florida Entomological Society will hold its 65th Annual Meeting on *10-13 August 1982* at The Colony on Longboat Key, Sarasota, Florida. The Colony is located at 1620 Gulf of Mexico Dr., Sarasota, FL 33580. Mailing address is P. O. Box 3949, Sarasota, FL 33578; telephone 813/383-5581. Suite rates will be $55.00 for a one floor suite (2 sleeping areas), and $85.00 for a two floor suite (2 BR, 2-bath, plus sleeping area). Pre-registration fee will be $25.00 ($10.00 student). Registration at the door will be $30.00 ($12.00 student). Banquet is included in registration fee. Questions concerning local arrangements should be directed to:

David M. Pomfret
Fahey Pest Control
P. O. Box 1452
Sarasota, FL 33578

If you plan to present a paper the tear out sheet must be completed and postmarked no later than *1 June*, and sent to:

Abe White, Program Chairman
817 W. Fairbanks Ave.
Orlando, FL 32804

Eight minutes will be allotted for presentation of oral papers, with 2 minutes for discussion. Also, for the first time any member may elect to present a poster paper at the evening session. Three oral student papers, judged best on content and delivery, will be awarded monetary prizes. Student authors *must* be Florida Entomological Society members and be registered for the meeting.

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SLIDE POLICY FOR ANNUAL MEETINGS

The following slide policy will govern slide presentations at the Annual Meetings. Only Kodak Carousel projectors for 2 x 2 slides will be available. However motion picture projectors will be available by special request to the Local Arrangements Chairman prior to the date of the meeting.

Authors should keep slides simple, concise, and uncluttered with no more than 7 lines of type on a rectangle 2 units high by 3 units wide. All printed information should be readable to an audience of 300 persons.

A previewing room will be designated for author's use. A projectionist will be available in the previewing room at least one hour before each session. Authors are expected to give the projectionist their slides in the previewing room prior to each session. Slides will be returned to the authors after each session in the meeting room.

Authors are expected to organize their slides in proper order in their personal standard Kodak Carousel slide tray (no substitution, please). Only a few slide trays will be available in the previewing room from the projectionist for hardship cases. Slides in the tray should be in correct order starting with slot #1 of the tray and positioned correctly (position of slides to go into tray: 1. upside down, and 2. lettering readable from this position upside down and from right to left). A piece of masking tape should be placed on the slide tray by the author and the following information should be written on the tape: 1. author's name, 2. session date, and 3. presentation time.

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