PYRAMICA BOLTONI, A NEW SPECIES OF LEAF-LITTER INHABITING ANT FROM FLORIDA (HYMENOPTERA: FORMICIDAE: DACETINI)

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ABSTRACT

The dacetine ant *Pyramica boltoni* is described from specimens collected in leaf litter in dry and mesic forest in central and northern Florida. It appears to be closely related to *P. dietrichi* (M. R. Smith), with which it shares peculiar modifications of the clypeus and the clypeal hairs. In total, 40 dacetine species (31 native and 9 exotic) are now known from southeastern North America.

Key Words: dacetine ants, Hymenoptera, Formicidae

RESUMEN

Se describe la hormiga Dacetini, *Pyramica boltoni,* de especimenes recolectados en la hojarasca de un bosque mésico seco en el área central y del norte de la Florida. Esta especie esta aparentemente relacionada con *P. dietrichi* (M. R. Smith), con la cual comparte unas modificaciones peculiares del clipeo y las cerdas del clipeo. En total, hay 40 especies de hormigas Dacetini (31 nativas y 9 exoticas) conocidas en el sureste de America del Norte.

The tribe Dacetini is composed of small ants (usually under 3 mm long) that generally live in leaf litter where they prey on small arthropods, especially springtails (Collembola). The tribe has been formally defined by Bolton (1999, 2000). Nearctic dacetines may be recognized by a combination of features exemplified in Fig. 1: expanded, lobed occipital area of the head, elongate, narrowed projection of the head beyond the eyes, and the elongate, narrow mandibles. Most species have enlarged, spoon-shaped or otherwise modified hairs on the head, especially on the clypeus, and whitish, spongy processes on the petiole and post-petiole, as in Fig. 1. In spite of their striking appearance, and a diversity of character states that allow easy recognition of most species, the dacetines remain poorly known. This can be attributed to their small size and cryptic habits.

There are only two Nearctic genera of Dacetini: *Strumigenys* and *Pyramica*. Other genera listed for this region, for example, in Bolton's 1995 catalog of ants, were synonymized by Bolton (1999) in his reclassification of the genera of the Dacetini. In addition, certain species that had been assigned to *Strumigenys* were referred to *Pyramica* on the basis of a series of fundamental character states. In practice, Nearctic *Pyramica* may be recognized by their broad, well separated mandibular bases, while *Strumigenys* have narrow mandibular bases that appear to be attached near the midline of the head (Bolton 1999). *Pyramica* species use their mandibles to seize and hold prey until it can be stung, while *Strumigenys* species are able to snap their mandibles shut with such force that the prey may be killed outright (Bolton 1999). Bolton (1999) presents a detailed discussion of generic distinctions and the evolution of mandibular structure in the Dacetini.

Dacetine ants show their greatest diversity in moist tropical regions. The revision of the tribe by Bolton (2000) includes 872 species, only 43 of which occur in North America north of Mexico. Southeastern North America has the great majority of Nearctic species, including, by my count, 31 native species and 9 introduced species. The native species appear to represent a Nearctic radiation; only 1 native species has a range that extends into the Neotropics. It has been suggested (Deyrup 1988) that the diverse southeastern fauna is composed of species that persisted in mesic southeastern refuges during the climatic shifts of the Pleistocene, providing a partial glimpse of what was once a much richer Arctotertiary woodland fauna.

With this background, it is not surprising that additional species of dacetine ants are still being discovered in the Southeast. Not only are these ants small and cryptic, but some species may have relictual geographic distribution in isolated patches of habitat, or they may be dependent on a specialized microhabitat that remains unknown.

Pyramica boltoni Deyrup, **new species**

Diagnosis of Worker (Fig. 1) and Queen

Distinguished from all other *Pyramica* by the following combination of character states: clypeus obtusely pointed, with four radiating, subapical, and two decumbent, apical hairs; two large, curved standing divergent hairs at apical third of clypeus; mandibles with toothless area (= "diastemma") basal to apical series of teeth barely visible in dorsal view. Otherwise, it is generally similar to *P. di-*

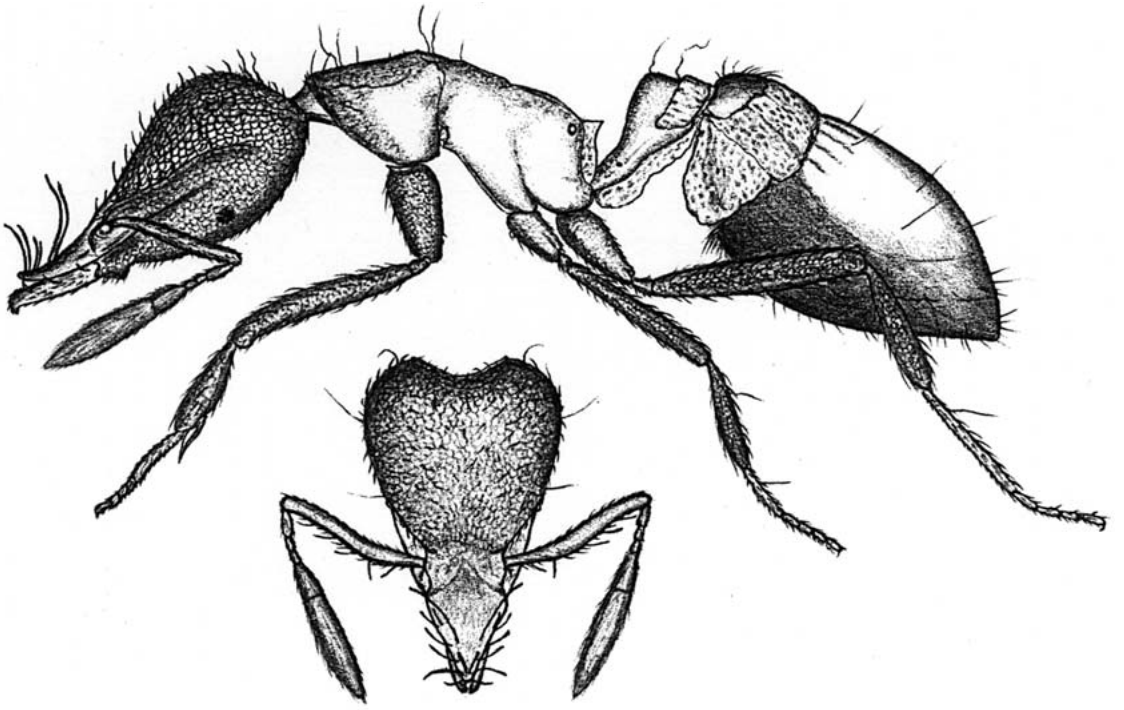

Fig. 1. *Pyramica boltoni*, new species, worker: lateral habitus view and frontal view of head; length: 1.6 mm.

etrichi (M. R. Smith) (see Discussion below and Fig. 2). On each mandible there are four enlarged subapical teeth, of which the first (basal) in the series is widest at the base, the third is about half the length of the two basal teeth, and the fourth is only slightly shorter than the first two.

Description of Holotype Worker

Measurements in mm: total length 1.66 (=length of head from clypeal apex to occipital margin + length mesosoma + length petiole, postpetiole, gaster); head length from clypeal apex to occipital margin: 0.47; maximum head width: 0.33; length of mesosoma: 0.45; length of petiole: 0.17; length of postpetiole + gaster: 0.57. The features described below are illustrated in Fig. 1: Clypeus in frontal view obtusely pointed, in lateral view slightly upturned apically; surface of clypeus smooth, without small discal hairs; large clypeal hairs as follows: two decumbent apical hairs extending laterally over mandibles; four radiating subapical hairs; five pairs of sublateral recurved hairs; one pair of stout, curved hairs, originating at apical third of clypeus, directed upward and outward. Frontal and occipital areas with sparse, suberect, curved hairs: one pair at apical quarter of antennal scrobe, one pair at sides of occipital lobes, one pair lateral, about midway between the other two. Mandibles with diastemma barely visible beyond clypeus in frontal view. Antennal scapes each with five elongate, suberect hairs on leading edge: a subbasal hair directed apically, a hair at basal third directed slightly basally, three hairs on apical half directed apically; scape otherwise with shorter, subreclinate, apically directed hairs. Pronotum shining, slightly rugose dorsally along sides in front; a pair of elongate, irregularly curved, fine hairs on dorsolateral carinae, another pair on dorsal posterior angles. Mesosoma shining laterally, obscurely reticulate-rugose dorsally; propodeal teeth short, triangular, infradental laminae weakly emarginate just below teeth. Petiole and postpetiole with well developed subapical and inferior spongiform lobes. Gaster shining, dorsal surface with a few, elongate, fine, erect hairs.

Description of a Paratype Dealate Queen

Measurements in mm: total length (measured as in worker):2.05; head length: 0.55; maximum head width: 0.37; length of mesosoma: 0.55; length of petiole: 0.25; length of postpetiole + gaster: 0.70. Structural character states similar to worker, except for presence of ocelli, large compound eyes, and modifications of the mesosoma associated with flight.

Type Material

Type localities and associated information, as appear on specimen labels. All specimens, as far

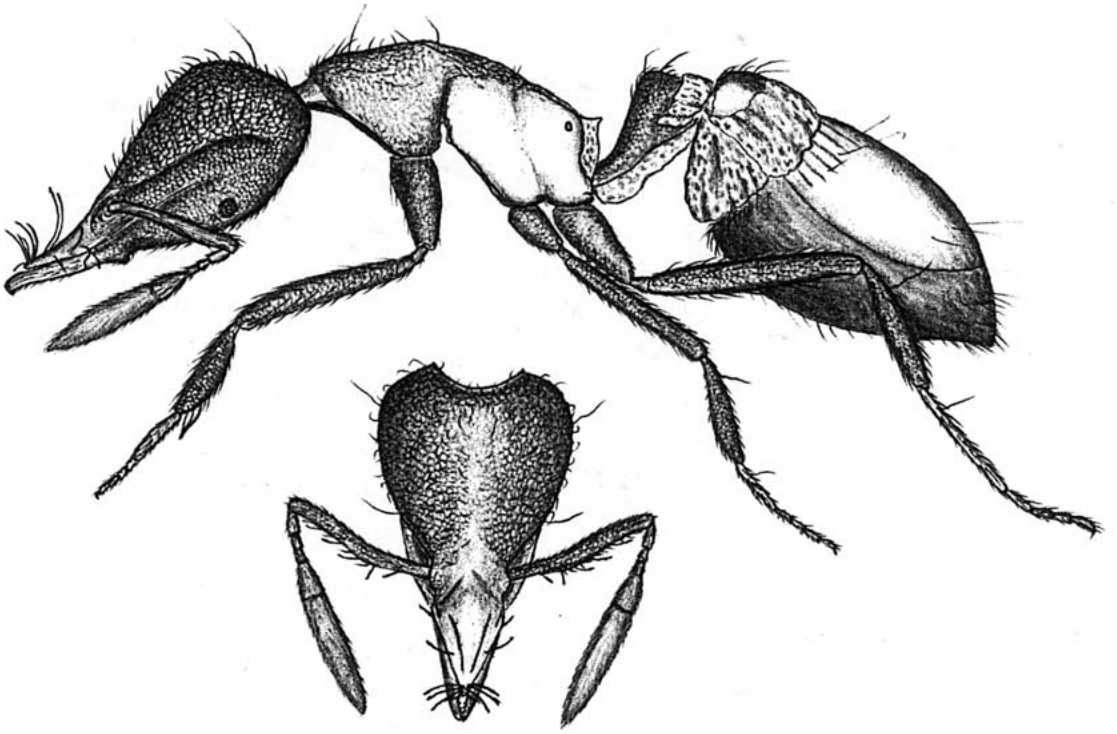

Fig. 2. *Pyramica dietrichi* (M. R. Smith), worker: lateral habitus view and frontal view of head; length: 1.8 mm.

as I know, were extracted from leaf litter, with various types of Berlese funnels. I have not seen any living specimens. Holotype worker: Florida: Highlands Co., Archbold Biological Station, 8-X-2004, M. Deyrup, at base of *Pinus elliottii* in pine and oak copse near cottage one. Paratype dealate queen used in description of queen: same site, habitat, collector as paratype, 14-X-2004. Additional paratype material: all paratypes from Florida; collector's initials: L. D.: Lloyd R. Davis, Jr.; M. D.: Mark Deyrup; C. J.: Clifford Johnson. Three workers: same locality as types, 6-II-1984, M. D., *Quercus geminata* and *Q. myrtifolia* litter; 1 worker: same locality as types, 26-I-1984, M. D., *Quercus laevis* litter; 1 worker: same locality as types, 18-I-1984, M. D., *Carya floridana* litter; 1 worker: same locality as types, 3-IX-1993, M. D. Indian River Co.: Vero Beach, 7-II-1993, M. D., pine and oak hammock, 20 workers, 1 queen; Martin Co.: Jonathan Dickinson State Park, 2-X-1988, M. D.,1 queen, 2 workers; Gilchrist Co.: Trenton, 1-X-1993, L. D., 1 worker; Dixie Co.: Old Town, 8 mi. north and 1.3 mi. east of Rt. 349, 11-V-1993, L. D., 2 workers; Old Town, 11-X-1993, L. D., 1 queen; St. John's Co.: St. Augustine, 1 mi. southwest on Rt. 207, 9-IV-1993, L. D.1 worker; Favor-Dykes State Park, 3-V-1987, C.J., xeric upland with *Quercus laevis* and *Q. myrtifolia*, 1 worker; Favor-Dykes State Park, 21-III-1987, C. J., *Quercus laevis* leaf litter, 1 worker; Favor-Dykes State Park, II-11-1994, M. D., mesic forest near campground, 2 workers; Citrus Co.: Holden, 5 mi. west, 25-IX-1993, L. D., 1 worker; Wakulla Co.: Ochlocknee State Park, 7-III-1986, C. J., oak leaf litter sample 637, 1 worker; Polk Co.: The Nature Conservancy Tiger Creek Preserve, 5-X-1989, M. D., leaf litter from *Quercus laevis* habitat, 2 workers; Jackson Co.: Florida Caverns State Park, 30-5-1988, Paul Skelley, 1 worker; Brevard Co.: Titusville, State Rd. 405, 10-IV-2003, Zachary Prusak, Enchanted Forest, leaf litter, 1 worker; Marion Co.: Ocala, 2.5 mi. north on Rt. 441, 13-VI-1993, L. D., 2 workers; Ocala, 9 mi. south southwest, 21-II-1993, M. D., sand pine scrub habitat, Ocala Waterway Scrub, 4 workers; Ocala National Forest, 23-VII-1992, M. D., sand pine scrub, 3 mi. south Big Scrub Campground on Rd. 588,1 worker; Ocala National Forest, 2-IX-1985, C. J. 1 mi. west of Juniper Springs on Rt. 40, sand pine scrub, 2 queens, 1 worker; Ocala, 1-II-1994, Zachary Prusak, State Rd. 484, 1.3 mi. west of I-75, sand pine scrub habitat,1 queen; Volusia Co.: Spruce Creek Nature Conservancy Preserve, 22-X-1994, M. D., 2 workers; Putnam Co.: Rodman Reservoir, 3-IV-1988, C. J., scrub just west of dam, sample 831, 4 workers; Ordway Preserve, 20-XI-1993, L. D., 0.5 mi. from main entrance, I worker; Ordway Preserve, 27-I-1995, L. D., Berlese funnel OK-012795, 1 worker; Florahome, 20-XII-1987, C. J., *Quercus laevis* sandhill 5 mi. north of Florahome, Rt. 100, 1 queen;

Alachua Co.: Hawthorne, 8-VI-1986, C. J., sand pine scrub 2.4 mi. east of town, 1 worker; Kanapaha Lake, 2-XI-1988, C. J., park near lake, oak litter, 1 worker; Cross Creek, 4-IV-1988, C. J., open xeric pine forest 2-3 mi. north of Cross Creek, 1 worker; Cross Creek, 2 mi. southeast, 7-IX-1986, C. J., hardwood litter sample 656B, 1 queen, 4 workers; Cross Creek, 4-VII-1985, C. J., 2 mi. southeast of Cross Creek, oak-palmetto litter, sample 370, 1 queen; Cross Creek, 4-VIII-1985, C. J., 6 mi. north of town, sample 425B, 1 queen; Gainesville, 31-XII-1988, C. J., flatwoods, county fairgrounds, sample 790, 1 queen; Gainesville, 13-VIII-1989, C. J., county fairgrounds, pine and palmetto litter, sample 1000, 1 worker.

Deposition of Type Material

Holotype, 13 workers, 2 queens: Museum of Comparative Zoology, Harvard University, Cambridge, MA; 8 workers, 2 queens: Florida State Collection of Arthropods, Gainesville, FL; 12 workers, 1 queen: Los Angeles County Museum of Natural History, Los Angeles, CA; remaining paratypes: collection of the Archbold Biological Station, Lake Placid, FL.

Etymology

The species is named for Barry Bolton, whose revisions of dacetine ants, culminating in his revision of the tribe (2000) have brought organization and logic to the group. He has enormously increased the number of identified specimens in collections, and has personally described several hundred species. His work on dacetines is presented with easily used keys and numerous illustrations, so that the group is, for the first time, accessible to a wide range of entomologists.

Discussion

Members of the genus *Pyramica* are usually most easily identified by characters of the head, especially the structures of the clypeus and mandibles and the modifications of the setae of the clypeus and antennal scapes. *Pyramica boltoni* shares clypeal character states with *P. dietrichi*, including the pointed clypeal shape with the tip turned up away from the plane of the mandibles, the decumbent apical setae, the set of radiating subapical setae, and the pair of elongate, curved setae arising near the apical third of the clypeus (Fig. 2). A third species, *P. ornata* (Mayr), shares these clypeal features, but the subapical setae are short and strongly expanded apically (Fig. 3). *Pyramica boltoni* is distinguished from *P. dietrichi* by having four, rather than six, radiating subapical setae, and by having the jaws protruding a shorter distance beyond the clypeus, so that the diastemma is barely visible in frontal view (Figs. 1 and 2). In addition, the sides of the pronotum of

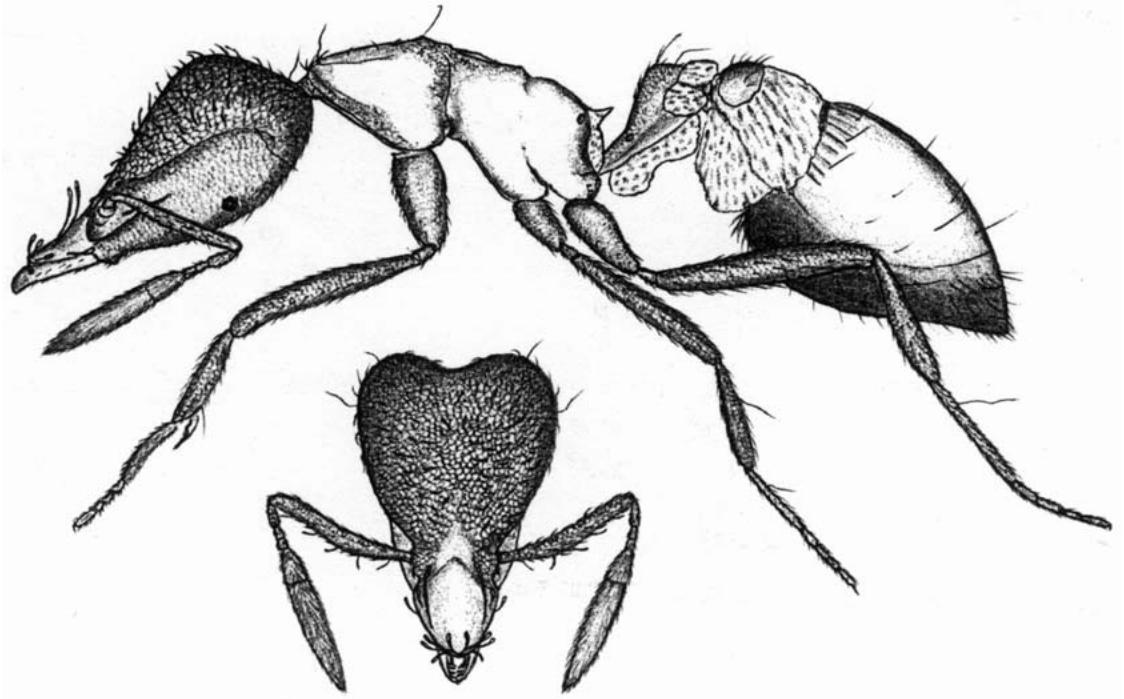

Fig. 3. *Pyramica ornata* (Mayr), worker: lateral habitus view and frontal view of head; length: 1.8 mm.

P. boltoni are primarily shiny, not reticulate as in *P. dietrichi* (Figs. 1 and 2). The pair of enlarged, upturned discal setae at the apical third of the clypeus are conspicuously larger than those of most *P. dietrichi*, but the size of these setae in *P. dietrichi* is somewhat variable, and it is possible that there might be overlap with those of *P. boltoni* in some populations. *Pyramica boltoni* keys to *P. dietrichi* in Bolton's (2000) key.

Several lines of evidence strongly suggest that *P. boltoni* is not a variant of *P. dietrichi*. The diagnostic features listed above are consistent in all the specimens examined from 38 separate collections spread over northern and central Florida. *Pyramica boltoni* is sympatric with *P. dietrichi*; there is no intergradation, and there are five known sites where both species occur. The diagnostic character states of the clypeal setae and the length of the mandibles relative to that of the clypeus are the kinds of character states that have been used in distinguishing many species of *Pyramica*, for example, in Bolton's key (2000). Unfortunately, these characters have not been associated with any natural history traits, but it is likely that such traits exist, given the consistency of the character states within each species of *Pyramica*.

Pyramica boltoni is known only from Florida, ranging from Highlands and Martin Cos. in the south-central Peninsula, north into St. John's Co. in the northeast corner of the state, and west into Jackson Co. in the central Panhandle. It might well occur in southern Georgia near the Florida border, but there are no known Georgia specimens. In Florida this species does not seem to be as widespread or abundant as *P. dietrichi*, which occurs throughout the state, including the Keys, north into Maryland and Illinois, and west into eastern Texas. I have examined 307 specimens of *P. dietrichi* from Florida, Georgia, Alabama, Arkansas, Oklahoma, Texas, and Illinois. Within the area where both species are known to occur, there is some evidence that *P. dietrichi* may occupy a wider range of habitats, specifically habitats that are wet, such as low flatwoods and swamp forest. Habitat information is available for 28 collections of *P. boltoni* and 49 collections of *P. dietrichi*; all specimens were extracted from leaf litter. Habitats of *P. boltoni* include xeric forest: 16 (57.1%); mesic forest: 11 (39.2%); wet forest, wet flatwoods: 1 (3.6%). Habitats of *P. dietrichi* include xeric forest: 23 (46.9%); mesic forest: 15 (30.6%); wet forest, wet flatwoods: 11 (22.4%). *Pyramica dietrichi* shows a significant difference in its greater preference for, or tolerance of, wet habitats (Chi square = 4.83, P value = 0.03).

Although the known distribution of *P. boltoni* is restricted relative to those of most native southeastern *Pyramica* species and it is not particularly common within this range, it cannot be considered a species that is rare or endangered. It is known from a series sites where its habitat might be expected to be protected including four state parks, one county park, two Nature Conservancy preserves, the Archbold Biological Station, the Ordway Preserve (managed by the University of Florida), and several sites in the Ocala National Forest.

Acknowledgments

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ONTHOPHAGUS YUCATANUS, A NEW SPECIES OF THE *CLYPEATUS* GROUP FROM MEXICO AND GUATEMALA (COLEOPTERA: SCARABAEIDAE)

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ABSTRACT

A new Mexican and Guatemalan species, *Onthophagus yucatanus*, belonging to the *Clypeatus* group is described and illustrated. The distinctive characters of this species, its geographical distribution, and habits are described.

Key Words: Scarabaeidae, *Onthophagus*, New species, Mexico, Guatemala

RESUMEN

Se describe e ilustra una nueva especie mexicana y guatemalteca, *Onthophagus yucatanus*, perteneciente al grupo *Clypeatus*. Se comentan sobre sus caracteres distintivos, así como su distribución geográfica y hábitos.

Translation provided by author.

The *Clypeatus* group of the worldwide genus *Onthophagus* Latreille, represents a heterogeneous and taxonomically difficult group of American species. According to Zunino & Halffter (1997) the *Clypeatus* group is formed by three species complexes, named *Clypeatus*, *Mirabilis*, and *Nasicornis*. However, delimitation of these complexes, and of all the groups of this genus, is vague and requires clarification based on phylogenetics approaches. At present we prefer, as did Howden & Gill (1993) and Kohlmann & Solís (2001), to exclude the species of the *Dicranius* and *Mirabilis* groups (*sensu* Howden & Gill 1993). In addition, we also exclude the species of the *Nasicornis* complex (*sensu* Zunino & Halffter 1997) from the *Clypeatus* group, primarily on the basis of the lack of tubercles and horns on the vertex, at least in the males.

Thus, the *Clypeatus* group would include only the following species: *O. clypeatus* Blanchard from Colombia, Ecuador, Peru, Bolivia, and French Guyana; *O. rhinophyllus* Harold from Venezuela and Colombia; *O. rhinolophus* Harold from Mexico and Guatemala; *O. belorhinus* Bates from Mexico and Guatemala; *O. xanthomerus* Bates from Colombia, Ecuador, and Peru; *O. praecellens* Bates from Costa Rica, Panama, and Colombia; *O. dicranoides* Balthasar from Ecuador; *O. lojanus* Balthasar from Ecuador; *O. maya* Zunino from Mexico and Belize; *O. propraecellens* Howden & Gill from Costa Rica and Panama; *O. andersoni* Howden & Gill from Costa Rica; *O. luismargaritorum* Delgado from Mexico; *O. veracruzensis* Delgado from Mexico; *O. coriaceoumbrosus* Kohlmann & Solís from Costa Rica; *O. graetaehelenae* Kohlmann & Solís from Costa Rica and Panama; *O. limonensis* Kohlmann & Solís from Costa Rica; *O. nemorivagus* Kohlmann & Solís from Costa Rica; *O. singulariformis* Kohlmann & Solís from Costa Rica; *O. viridivinosus* Kohlmann & Solís from Costa Rica and *O. notiodes* Solís & Kohlmann from Costa Rica (Zunino & Halffter 1997; Delgado & Pensado 1998; Kohlmann & Solís 2001; Solís & Kohlmann 2003). Distribution of these species is almost restricted to the tropical rain forests in areas generally below 1,000 m asl. In contrast to the extensive coprophagy of many species of *Onthophagus*, most species of this group show a strong tendency towards feeding on rotting fruit and carrion (Zunino & Halffter 1997).

In two recent studies on the fauna of coleopterous Scarabaeidae of the Península de Yucatán, Mexico (Peraza 2004, unpublished data), and of the region of Petén, Guatemala (Cano 1998, unpublished data), several specimens were obtained which represent an undescribed species of *Onthophagus*. We describe it here in the *Clypeatus* group.

Onthophagus yucatanus, **new species**
(Fig. 1, 4)

Type Material

Holotype: "MÉXICO: Yucatán, Tzucacab, Tigre Grande, 17-X-2001. 0900-1730 horas, coprotrampa (humano), L. N. Peraza-Flores col.". Allotype same data as holotype, except: 20-VIII-2001. Both deposited in the Entomological Collection (IEXA) of the

Instituto de Ecología, A. C. (Veracruz, Mexico). Paratypes (116 ♂♂, 132 ♀♀) same data as holotype, except: 19-VIII-2001 (1 ♂, 6 ♀♀); 20-VIII-2001 (14 ♂♂, 6 ♀♀); 17-18-IX-2001, 18:00-09:00 hrs (1 ♀); 18-19-IX-2001, 18:00- 09:00 hrs (4 ♂♂, 10 ♀♀); 19-IX-2001, 09:00-18:00 hrs (14 ♂♂, 7 ♀♀); 19-20-IX-2001, 18:00-09:00 hrs (3 ♂♂, 7 ♀♀); 17-X-2001, 09:00-17:30 hrs (25 ♂♂, 28 ♀♀); 17-18-X-2001, 17:30-08:00 hrs (10 ♂♂, 9 ♀♀); 16-XI-2001, 08:30-17:30 hrs (6 ♂♂, 5 ♀♀); 16-17-XI-2001, 17:30-09:00 hrs (4 ♀♀); 17-XI-2001, 09:30-17:30 hrs (2 ♂♂, 6 ♀♀); 17-18-XI-2001, 17:30-07:00 hrs (2 ♂♂); 15-16-XII-2001, 17:00-08:30 hrs (1 ♂, 2 ♀♀); 16-XII-2001, 08:30-17:20 hrs (2 ♂♂, 5 ♀♀); 13-I-2002, 09.00-17:30 hrs (1 ♂, 3 ♀♀); 11-12-II-2002, 17:15- 08:30 hrs (1 ♂, 1 ♀); 12-II-2002, 08:30-17:30 hrs (3 ♂♂, 4 ♀♀); 12-II-2002, 17:30-09:00 hrs (2 ♂♂, 2 ♀♀); 13-II-2002, 09:00- 19:35 hrs (1 ♀); 13-14-II-2002, 17:35-08:00 hrs (1 ♂); 11-12-III-2002, 17:30- 09:30 hrs (1 ♀); 12-III-2002, 09:30-18.00 hrs (3 ♂♂, 2 ♀♀); 13-III-2002, 09:00-18:00 hrs (1 ♂, 1 ♀); 13-14-III-2002, 18:00-09:00 hrs, (3 ♂♂, 1 ♀); 19-IV-2002 (1 ♂); 14-V-2002, 10:00-18:30 hrs (3 ♂♂, 2 ♀♀); 14-15-V-2002, 18:30-10:00 hrs (1 ♂, 1 ♀); 10-12-VI-2002 (2 ♀♀); 10-12-VII-2002, 18:30-08:30 hrs (3 ♂♂, 5 ♀♀); 13-V-2002, excremento de perro (1 ♀); 20-VIII-2001-17-IX-2001 NTP80 (1 ♀); 17-IX-2001-17-X-2001, NTP80 (1 ♀); 17-X-2001-16-XI-2001, NTP80 (1 ♂); 16-XI-2001-16-XII-2001, NTP 80 (1 ♀); 13-II-2002-11-III-2002, NTP80 (1 ♀); 15-V-2002-12-VI-2002, NTP80 (4 ♂♂); 12-VI-2002-12-VII-2002, NTP80 (1 ♀); 12-VII-2002-17-VIII-2002, NTP80 (1 ♂). "GUATEMALA: Petén, Aldea Carmelita, Campamento Chuntuquí, 24-25-II-1996, bosque alto, 17°32'N 90°07'W, E. Cano col." (2 ♂♂, 1 ♀); same data as anterior, except: Campamento El Naranjo, 25-II-1996, heces de jaguar, E. Cano col. (1 ♀); San Miguel la Palotada, 16-III-1999, M. Jolón col. (1 ♂, 1 ♀); San Miguel la Palotada, 7-VIII-1999, M. Jolón col. (1 ♀). Twenty paratypes deposited in each one of the following collections: Florida State Collection of Arthropods (Gainesville, United States), Canadian Museum of Nature (Ottawa, Canada) and Instituto de Biología de la Universidad Nacional Autónoma de México (Mexico City); 151 paratypes deposited in the Instituto de Ecología, A. C. (Veracruz, Mexico); seven paratypes deposited in the Universidad del Valle de Guatemala (Guatemala City); and ten paratypes deposited in each one of the following collections: Cuauhtémoc Deloya Collection (Veracruz, Mexico), Lizandro N. Peraza Collection (Yucatán, Mexico) and Leonardo Delgado Collection (Mexico City).

Description

Holotype male (Fig. 1, 2). Length: 5.4 mm, maximum width (at basal third of elytra): 3.3 mm. Small, ovate, dorsally glabrous; dorsal color metallic dark green with very slight cupreous reflections on head, anterolateral regions of pronotum dull, venter with same color as dorsum but with cupreous reflections more pronounced, femora and tibiae completely reddish green, tarsi reddish. Clypeus triangular, with apical third obliquely reflexed, apex acuminated, sides slightly and evenly sinuated to the genae; clypeus moderately concave, fronto clypeal region feebly convex, frons flattened, genae slightly convergent forward; vertex with two slender, divergent horns, bases of horns well separated and arising at level of posterior portion of eyes, horns slightly below the top of pronotum. Head with punctures small, shallow and sparse, shallower and finer towards apex and vertex.

Pronotum with anterior right angles and somewhat projected, lateral borders strongly curved in front of middle, posterior angles almost evenly rounded to base. Disc and posterolateral portions of pronotum swollen; anterior third declivous with two longitudinal, obtuse tubercles in front of disc, tubercles slightly divergent and separated by a shallow concavity widened forward; tubercles and lateral portions of pronotum delimiting two very feeble concavities. Pronotum with moderately large, ringed punctures, denser and larger at anterior angles; lateral concavities and anterior angles with finely reticulate punctation; anterior concavity almost smooth; pronotal base finely margined with a row of small punctures. Elytra with evident humeral and apical calli; elytral striae marked by double line crenulated by medium-size punctures; intervals with fine, shallow punctures and rugosities, denser to lateral intervals.

Metasternum convex with dense, ringed punctures. Abdominal sternites shagreened, with a row of small punctures adjacent to anterior margin, each puncture bearing a yellowish seta; sixth abdominal sternite narrowed medially. Pygidium strongly convex to apical third, surface with large and deep punctures moderately dense, each puncture bearing a small, yellowish seta. Protibiae with inner border evenly curved, outer border quadridentate with teeth situated at distal middle, apex with inner projection bearing a brush of setae; apical spur elongate and curved outside. Apex of meso and metatibiae with a row of small spinules intermixed with long setae. Genitalia with parameres strongly projected ventrally, dorsally flattened and with apices parallel.

Allotype female (Fig. 1, 4). Length: 5.3 mm, maximum width (at basal third of elytra): 3.3 mm. Differs from holotype in the following respects: anterolateral regions of pronotum scarcely dull; clypeus semitrapezoidal, slightly emarginated at middle, anterior margin very scarcely reflexed and with sides almost straight to the genae; frontoclypeal region carinated from side to side; frons with two rounded, transversal tubercles situated slightly behind of anterior border of eyes; vertex without horns; clypeus with strongly

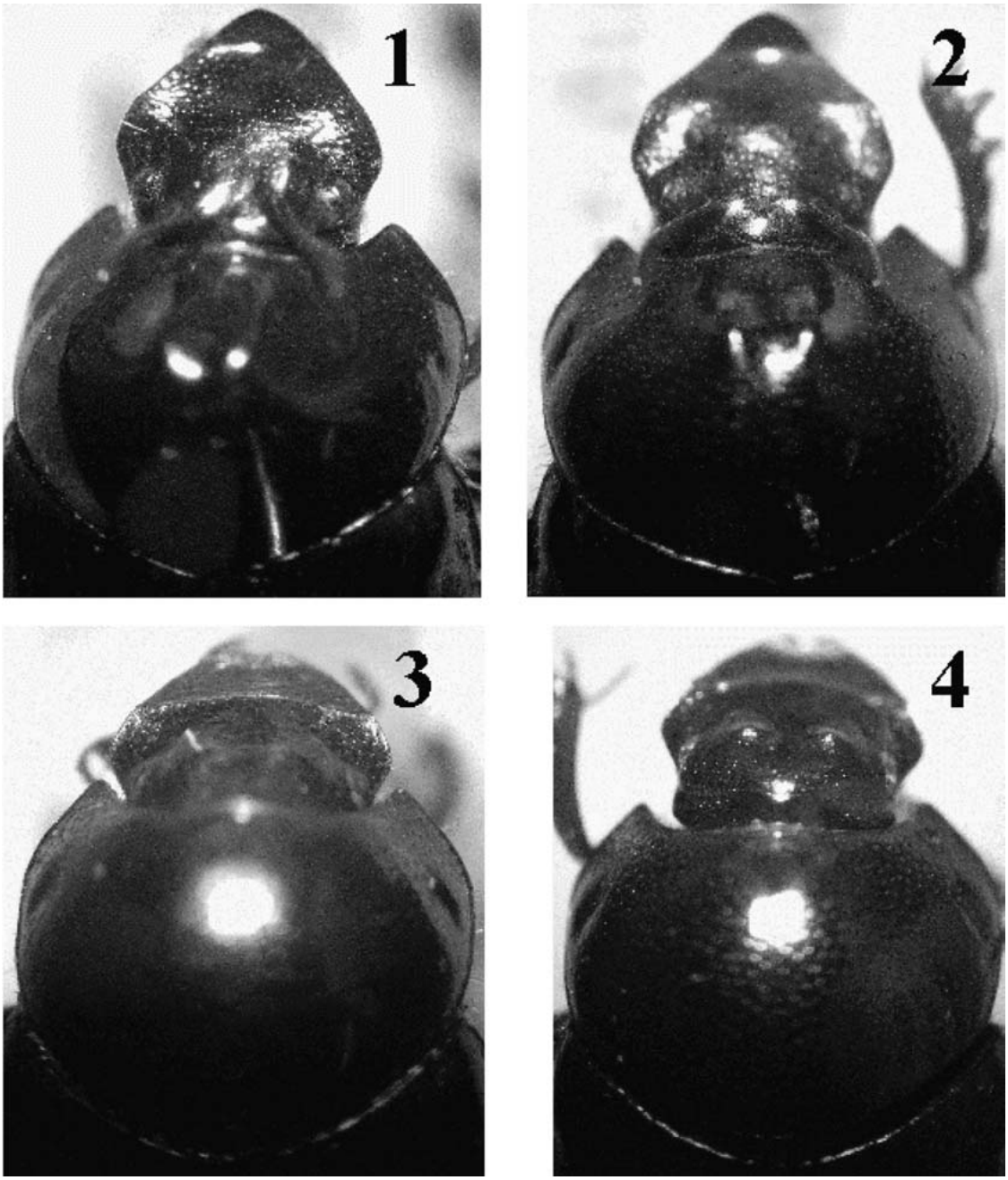

Fig. 1. Dorsal view of head and pronotum of *Onthophagus* spp. 1, male of *O. luismargaritorum* Delgado. 2, male of *O. yucatanus* **sp. nov.** 3, female of *O. luismargaritorum* Delgado. 4, female of *O. yucatanus* **sp. nov.**

rugose punctation, genae with coarse punctures; pronotum with anterior angles not projected, almost evenly convex, only with a small, central concavity adjacent to anterior margin; pronotum with finely reticulate punctation restricted to anterior angles; sixth abdominal sternite not narrowed medially; protibiae slightly broader and without inner projection and brush of setae; apical spur longer.

Variation in the series of paratypes (113 ♂♂, 128 ♀♀).—Length: 3.5-5.6 mm, maximum width (at basal third of elytra): 2.3-3.6 mm. The dorsal color varies from dark green to blue; size of punctures on elytra varies moderately in both sexes; in

the smaller males the clypeus is scarcely reflexed and the cephalic horns are reduced to small, transverse tubercles, the pronotum is nearly evenly convex, with only a small concavitiy flanked by two small rounded tubercles; in the smaller females the pronotum is evenly convex, lacking anterior concavity.

Type Locality

Mexico, Yucatán, Tzucacab, Tigre Grande (19°42'36"N 89°02'28"W).

Etymology

The specific epithet derives from Yucatán, the name of the Mexican state where this species was collected.

Taxonomic Remarks

Onthophagus yucatanus shares several characters with *O. luismargaritorum*. Both species are distinguished from the remaining species in the *Clypeatus* group by the following combination of characters: major males with clypeus obliquely reflexed and acuminated (not rectangular, rounded or with a projection "T" shaped), the horns on the vertex arising between the eyes (not arising behind the eyes) and the protibiae short and wide (not elongate and slender), and the females with the tubercles on the vertex situated at level of the anterior border of eyes (not at level of the posterior border of eyes), and the pronotum without tubercles.

The two species are separated by the following characters: males and females of any size of *O. yucatanus* by the dorsal color metallic dark green or blue with very slight cupreous reflections on head and larger and denser ringed punctures of the pronotum, not with dorsal color strongly metallic cupreous green and small and sparse ringed punctures of pronotum as in *O. luismargaritorum*; major males of *O. yucatanus* with the central tubercles of pronotum obtuse and with the central concavity widened to anterior margin (Fig. 1, 2), not with tubercles rounded and the central concavity with same wide from tubercles to anterior margin as in *O. luismargaritorum* (Fig. 1, 1). Females of any size of *O. yucatanus* with the cephalic tubercles transverse (Fig. 1, 4), not with cephalic tubercles oblique as in females of *O. luismargaritorum* (Fig. 1, 3) and major females of *O. yucatanus* with a small concavity adjacent to anterior margin of pronotum, not with pronotum evenly convex as in females of *O. luismargaritorum*.

Distribution

Onthophagus yucatanus is known from the type locality, situated in the central region of the Península de Yucatán, Mexico, and from the region of Petén, Guatemala. Both areas present tropical moist subdeciduous forest with low altitude. Extensive sampling in other localities in the northern peninsula with dry deciduous forests produced no specimens of this species.

Habits

At the type locality, specimens of *O. yucatanus* were caught with traps baited with human excrement and with traps baited with rotting squid. Two hundred and thirty one specimens were obtained in the coprotraps and only 11 in the necrotraps. This feeding preference contrasts with that of most species of the *Clypeatus* group, which are captured primarily at rotting fruit and carrion. Only *O. luismargaritorum* shares the same preferences, with 83% of the specimens known of this species collected at human and cow dung, and only 17% with necrotraps (Delgado 1995).

Although many specimens were collected during the day (124) in comparison to those caught during the night (75), more data are needed to define the daily activity of this species.

Acknowledgments

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TOXICITY OF PESTICIDES USED IN CITRUS TO *APROSTOCETUS VAQUITARUM* (HYMENOPTERA: EULOPHIDAE), AN EGG PARASITOID OF *DIAPREPES ABBREVIATUS* (COLEOPTERA: CURCULIONIDAE)

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ABSTRACT

Twelve pesticides used in citrus were tested for their contact toxicity to *Aprostocetus vaquitarum* Wolcott (Hymenoptera: Eulophidae) a parasitoid of *Diaprepes abbreviatus* (L.) (Coleoptera: Curculionidae). Sevin® 80 WSP, Malathion 5 EC, and Imidan® 70 WSB resulted in the most rapid death of *A. vaquitarum* adults. Admire® 2F, Danitol® 2.4EC, and Surround® WP were also very detrimental. Kocide® 101 WP, Citrus Soluble Oil, Micromite® 80 WGS, Acramite® 50 WS, Micromite® 80 WGS + Citrus Soluble Oil, Aliette WDG, and Agrimek® 0.15 EC + Citrus Soluble Oil were slightly to non-toxic to *A. vaquitarum*. The relative toxicity of the pesticides was consistent up to four weeks after application. Significantly fewer adult *A. vaquitarum* emerged from *D. abbreviatus* eggs laid on foliage treated in the field with Sevin® XLR and Imidan® 70 WSB than emerged from the water treated control. Field residues of Sevin® XLR remained toxic for seven days while the effects of Imidan® 70 WSB were no longer significant after one week. The number of *A. vaquitarum* adults emerging from host eggs laid on treated foliage was not significantly different among Micromite® 80 WGS, Acramite® 50 WS, and the control, but significantly fewer adults emerged from foliage treated with either Micromite® 80 WGS + Citrus Soluble Oil or Citrus Soluble Oil alone. There were no significant differences between oviposition or new generation adults when *A. vaquitarum* was exposed to Micromite® 80 WGS or a water control.

Key Words: insecticides, diflubenzuron, selectivity, toxicity, citrus IPM, biological control

RESUMEN

Se estudió la toxicidad de varios plaguicidas aplicados comúnmente en cítricos para *Aprostocetus vaquitarum* Wolcott (Hymenoptera: Eulophidae) un parasitoide de *Diaprepes abbreviatus* L. (Coleoptera: Curculionidae). Sevin® 80 WSP, Malathion 5 EC, e Imidan® 70 WSB fueron los que más rápidamente causaron la muerte de *A. vaquitarum*. Admire® 2F, Danitol® 2F, Danitol® 2.4 EC y Surround® WP fueron muy tóxicos para el parasitoide. Comparados con el testigo absoluto, Kocide® 101 WP, aceite soluble de cítricos, Micromite® 80 WGS, Acramite® 50 WS, Micromite® 80 WGS + aceite soluble de citricos, Aliette WDG y Agrimek® 0,15EC + aceite soluble de cítricos no resultaron significativamente tóxicos para el parasitoide. La toxicidad relativa de estos plaguicidas se mantuvo durante un período de 4 semanas. Emergieron significativamente menos adultos de *A. vaquitarum* de huevos de *D. abbreviatus* que habían sido depositados en hojas tratadas en el campo con Sevin® XLR e Imidan® 70 WSB en comparación con aquéllos que emergieron de huevos depositados en hojas tratadas con agua. Los efectos tóxicos de Sevin® XLR continuaron por 1 semana, mientras que los efectos de Imidan dejaron de ser significativos después de 1 semana. No hubo diferencias significativas entre el número de adultos *A. vaquitarum* emergidos de huevos de *D. abbreviatus* en follaje tratado con Micromite® 80 WGS y Acramite® 50 WS comparado con el testigo absoluto. Sin embargo, sí las hubo con Micromite® 80 WGS + aceite soluble de cítricos o con el aceite soluble de cítricos cuando este ultimo fue aplicado solo. No hubo diferencias significativas ni en la puesta ni en la emergencia de una nueva generación de parasitoides cuando se expuso las hembras a Micromite® 80WGS en comparación con aquéllas que se expuso al agua (testigo absoluto).

Translation provided by the authors.

Pesticides are a critical component of insect pest management in citrus production. Insect fauna affected by pesticide applications often encompasses a group extending beyond the pest species targeted. Of particular concern are beneficial insects which play a vital role in suppressing pest insect populations. Non-selective pesticide application can disrupt beneficial insect pop-

ulations and may lead to outbreaks of pest insects (Barbosa & Schultz 1987). Much of Florida's citrus production is intended for juicing, which requires a less severe pesticide regime than the fresh fruit market (Michaud & Grant 2003). However, populations of specific pests, such as the root weevil, *Diaprepes abbreviatus* (L.) (Coleoptera: Curculionidae), regularly necessitate the use of broad spectrum insecticides (Timmer et al. 2005).

Diaprepes abbreviatus is native to the Caribbean and was presumably introduced from Puerto Rico. It was first reported in Florida in 1964 and is established across the citrus-producing regions of the state (Woodruff 1964). *Diaprepes abbreviatus* feeds on >270 species of plants from 59 families (Simpson et al. 1996). It is a significant pest for ornamental growers and is economically very important in the citrus industry where it is estimated to cost producers over 70 million dollars annually (Stanley 1996). Adult weevils feed along the edges of leaves leaving characteristic semi-circular notches but the most significant damage is done by larvae feeding on the root system which can weaken or kill the plant. Root feeding also may leave the plant more susceptible to root rot organisms such as *Phytophthora* spp. (Timmer et al. 2005). Though there is evidence that soil-applied pesticides may be effective against larvae (McCoy et al. 1995), pesticide regimes often target the adult stage with foliar applications, particularly during periods of new citrus growth.

Biological control is a vital component in an ongoing effort toward an integrated pest management system for *D. abbreviatus*. In the late 1990s, programs were initiated to introduce hymenopteran egg parasitoids from the Caribbean islands into Florida. In 2000 the ecto-parasitoid *Aprostocetus vaquitarum* Wolcott (Hymenoptera: Eulophidae) was introduced into Florida from the Dominican Republic (Jacas et al. 2005). *Aprostocetus vaquitarum* has been mass reared and released in several Florida counties since 2000 and is now considered to be established in parts of southern Florida (Jacas et al. 2005). *Aprostocetus vaquitartum* is one of the principal parasitoids of *D. abbreviatus* in its native range, and in areas where it has become established in south Florida, egg mortality rates of 70-90% have been observed (Peña et al. 2005).

Very little is known about the toxicity of insecticides used in citrus production to parasitoids of *D. abbreviatus*. Two products were tested against two other *D. abbreviatus* egg parasitoids (Amalin et al. 2004) but no information exists on the relative toxicities of commonly used pesticides to *A. vaquitarum*. Our study was initiated to determine the relative toxicities of several pesticides used in Florida citrus production to *A. vaquitarum*. Four pesticides registered for control of *D. abbreviatus* and three insecticides registered for other citrus insect pests were examined, as well as four mite control products and two fungicides. The contact toxicity of the pesticides was evaluated in the laboratory. Some products were also tested further in the field. Information on the relative potency of these crop protection products could be of use in the development of *D. abbreviatus* management strategies aimed to minimize adverse impacts on beneficial insects such as *A. vaquitarum*.

Materials and Methods

Pesticides

Twelve pesticides labeled for use against *D. abbreviatus* in Florida were tested for toxicity to *A. vaquitarum* (Table 1). The application rate for each pesticide was based on the 2005 Florida Citrus Pest management Guide (Timmer et al. 2005). All commercially formulated pesticides were diluted in water to an application rate of 935.4 liter/ha (100 gal/ac).

Pesticide Toxicity Trial

To test the toxicity of the 12 pesticides listed above, female *A. vaquitarum* (<72 h old) were exposed to the recommended field application rate of each commercial formulation. Filter paper (Fisherbrand® Filter Paper, P4 Medium-Fine porosity, slow flow rate, Cat. no.: 09-803-6G) was dipped in a mixed pesticide or a water control for 3 seconds and air dried for 2.5 h. The treated filter paper was then cut into 0.5 cm × 5.0 cm strips. Female *A. vaquitarum* were placed one individual per tube into 10-ml test tubes. A smear of honey was provided on the inner surface of each test tube as a food source and the open end of the test tube was covered with 2 ply of kimwipe (Kimberly-Clarke®, Kimwipes® EX-L) secured with rubber tubing to allow ventilation. The kimwipe was moistened with water daily. Pesticide-treated and control filter paper strips were placed in the test tubes and each parasitoid was examined for signs of life 8, 16, 24, 48, 72, and 96 h after exposure. Mortality was assessed under a 50× dissecting microscope. An insect was recorded as dead if it did not move or twitch in a 10-s period. The experiment was repeated 4 times with 10 to 14 individuals in each replicate for each treatment. Two of the four replicates also were monitored at 24-hour intervals until 100% mortality was achieved to assess longevity.

An experiment was carried out exactly as above with pesticide strips tested at intervals of 7 d, 14 d, and 21 d after pesticide application for treatments that resulted in higher mortality than the control when tested 0 d after application. Pesticide and control strips were weathered out of doors and protected from precipitation and direct

TABLE 1. LIST OF PESTICIDES TESTED, INCLUDING TRADE NAME, CLASS, ACTIVE INGREDIENT AND APPLICATION RATE.

Trade name	Class	Active ingredient	Application rate (product/1 litre water)	Manufacturer
Sevin 80 WSP[1]	Carbamate	Carbaryl (80%)	12.0 g	Bayer CropScience
Sevin XLR[1]	Carbamate	Carbaryl (44.1%)	10.0 ml	Bayer CropScience
Malathion 5 EC[1]	Organophosphate	Malathion (57%)	7.5 ml	Micro Flo Company
Imidan 70 WSB[1]	Organophosphate	Phosmet (70%)	2.4 g	Gowan Company
Admire 2 F[1]	Neonicotinoid	Imidacloprid (22%)	2.5 ml	Bayer CropScience
Danitol 2.4 EC[1]	Pyrethroid	Fenpropathrin (30.9%)	1.6 ml	Valent USA Corporation
Surround WP[1]	Kaolin clay	Kaolin clay (95%)	60.0 g	Engelhard Corporation
Kocide 101 WP[2]	Copper fungicide	Copper hydroxide (77%)	14.4 g	Griffin l.l.c
Alliete WDG[2]	Phosphonate	Aluminium tris (80%)	6.0 g	Bayer CropScience
AgriMek 0.15 EC'	Glycoside	Abmectin (2%)	0.5 ml	Syngenta
Citrus Soluble Oil[3]	Petroleum oil	Petroleum oil (99.3%)	10.0 ml	Platte Chemical Company
Micromite 80 WGS[3]	IGR	Diflubenzuron (80%)	0.47 g	Crompton Manufacturing Company, Inc.
Acramite 50 W5[3]	Unknown	Bifenazate (50%)	1.2 g	Crompton Manufacturing Company, Inc.

[1]Insecticide, [2]Fungicide, [3]Miticide.

sunlight in 1.5-liter wax paper dishes with perforated fitted plastic lids. All experiments were conducted in a walk-in growth chamber with a 16:8 (L:D) photoperiod, 23°C night:26°C day temperature regime, and 58-60% RH. Percent mortality was corrected with Abbott's Formula: $100 \times (1 - \%$ surviving on treatment/surviving on control) (Abbott 1925). Longevity of *A. vaquitarum* on the different treatments was compared by one-way ANOVA. Mean separations were performed with the Tukey HSD method ($\alpha = 0.05$) (Statistix® 8 Analytical Software, 2003).

Effect of Residual Pesticide on Parasitism

To test the residual effects of specific pesticides on *A. vaquitarum*, products were applied out of doors to 1-1.5 m tall green buttonwood (*Conocarpus erectus* L.) host plants. In the first of two experiments Sevin® XLR, Imidan® 70 WSB, and a water control were tested in a randomized complete block design, and replicated 3 times with 3 green buttonwood plants per replicate. Treatments were applied with a hand-gun sprayer operating at 2413 kPa (350 psi) and delivering 935.4 liter/ha of finished spray (~3.79 liter/tree). Four hours after treatment, 15-cm long branches from each treatment ($n = 30$) were placed in 500-ml plastic containers with water and offered to 150 field collected *D. abbreviatus* inside $30 \times 30 \times 30$-cm plexiglass cages. After being exposed to *D. abbreviatus* for 12 h, the branches with egg masses were removed and placed inside a clean plexiglass cage into which female *A. vaquitarum* (2 per egg mass) were released. The *A. vaquitarum* females were removed after 48 h. The branches remained in water for a further 72 h after which the egg masses were cut from the branches with scissors and placed into individual 10-ml test tubes until emergence. Host plant material from each treatment was collected 7 and 14 d after being sprayed and was exposed to *D. abbreviatus* and *A. vaquitarum* as above.

In a separate experiment Micromite® 80 WGS, Acramite® 50 WS, Citrus Soluble Oil, Micromite® 80 WGS + Citrus Soluble Oil, and a water control were tested with green buttonwood host plants exactly as described in the preceding paragraph. Data for both experiments were analyzed with a Kruskal-Wallis ANOVA (Statistix® 8 Analytical Software, 2003).

Micromite® 80 WGS Fecundity Trial

To test the effects of the insect growth regulator Micromite® 80 WGS on fecundity, female *A. vaquitarum* (<48 h old) were exposed to filter paper strips (1 cm × 5 cm) treated with Micromite® 80 WGS or a water control and placed in 9-cm diameter petri dishes. A smear of honey was placed on the inner surface of the lid as a food source, and a water soaked cotton disc (1 cm diameter, 0.3 cm height) was placed in the dish. A 3-cm diameter hole was cut in the lid and covered with fine mesh to provide ventilation. Females were exposed to each treatment for 70 h. After 70 h, one *D. abbreviatus* egg mass (<48 h old) was introduced into the dish. The two leaves which contained the egg mass were left intact and the petioles were inserted into a water soaked block of florist's foam covered in aluminum foil. The egg mass was exposed to a female for 24 h and then removed. A total of three egg masses were offered to each female at 24-h intervals. Fifty females were used for each treatment; a sub-sample of egg masses from 20 of the females on each treatment

was dissected 40 h after being exposed. The egg masses from the other 30 females were reared to emergence. Egg masses opened after 48 h were examined under a dissecting microscope to determine the stage of *A. vaquitarum* development. The number of adult *A. vaquitarum* and the number of *D. abbreviatus* eggs available in each egg mass were calculated at the completion of the experiment with aid of a dissecting microscope. The experiment was conducted in a growth chamber, with conditions as above. Data were subjected to a Kruskal-Wallis ANOVA to analyze oviposition and adult emergence as well as detect significant differences between the means ($\alpha = 0.05$) (Statistix® 8 Analytical Software, 2003).

Results

Pesticide Toxicity Trial

When the pesticides were tested on the day of application, Sevin® 80 WSP, Malathion 5 EC, and Imidan® 70 WSB resulted in more rapid death of *A. vaquitarum* than the other products or the control ($F_{13,322} = 27.5$, $P < 0.001$) (Table 2). Females survived only 15.3 ± 1.7 h on Sevin® 80 WSP. The pesticides Kocide® 101, Citrus Soluble Oil, Micromite® 80 WGS, Acramite® 50 WS, Micromite® 80 WGS + Citrus Soluble Oil, and Agrimek® 0.15 EC + Citrus Soluble Oil were not significantly different from the control on which *A. vaquitarum* survived 122 ± 10.1 h. Admire® 2 F, Danitol® 2.4 EC, Surround® WP, and Aliette were intermediate. Seven days after application, Sevin® 80 WSP, Malathion 5 EC, and Imidan® 70 WSB once again resulted in the most rapid death of *A. vaquitarum* which survived only 18.4 ± 1.4 h on Sevin® 80 WSP ($F_{9,270} = 40.5, P < 0.001$) (Table 2). Aliette, Kocide®101, and Agrimek® 0.15 EC + Citrus Soluble Oil were not significantly different from the control on which females survived a mean of 123.4 ± 9.3 h. Admire® 2 F, Danitol® 2.4 EC and Surround® WP resulted in intermediate survival times. Fourteen days after application Sevin® 80 WSP resulted in the most rapid death (16.4 ± 1.2 h) followed by Malathion 5 EC, Imidan® 70 WSB, Admire® 2F, Kocide®101, Danitol® 2.4 EC, and Surround® WP. Agrimek® 0.15 EC + Citrus Soluble Oil was not different from the control on which females survived for a mean of 124.8 ± 17.3 h ($F_{8,171} = 16.7, P < 0.001$) (Table 2). Twenty-one days after application Sevin® 80 WSP, Malathion 5 EC, and Imidan® 70 WSB again resulted in the most rapid death of *A. vaquitarum*, which survived 24.0 ± 2.5 h on Sevin® 80 WSP. Admire® 2 F, Danitol® 2.4 EC, and Surround® WP resulted in intermediate survival time, while Kocide®101 and Agrimek® 0.15 EC + Citrus Soluble Oil were not significantly different from the control on which females survived for a mean of 173.2 ± 21.2 h ($F_{8,198} = 25.5, P < 0.001$) (Table 2).

Sevin® 80 WSP was the most toxic pesticide when *A. vaquitarum* was exposed to the pesticides on the same day as pesticide application, resulting in 24% mortality after 8 h and 98% mortality after 24 h (Table 3). Malathion 5 EC and Imidan® 70 WSB were the only other products which resulted in mortality after 8 h, and following Sevin® 80 WSP were the most toxic of the products tested resulting in 100 and 98% mortality, respectively, after 48 h. All three products resulted in 100% mortality of *A. vaquitarum* by 72 h. Admire® 2 F and Danitol® 2.4 EC were the next most lethal products resulting in 96 and 85% mortality by the

Table 2. Mean time of death (h ± S.E.) after exposure to each pesticide treatment.

	Time after application			
Treatment	0 d	7 d	14 d	21 d
Sevin 80 WSP	15.3 (1.7) e	18.4 (1.4) c	16.4 (1.2) d	24.0 (2.5) d
Malathion 5 EC	26.0 (3.4) e	23.1 (2.4) c	33.2 (3.1) cd	25.4 (2.3) d
Imidan 70 WSB	23.0 (3.6) e	25.1 (2.4) c	45.6 (6.6) bcd	42.1 (4.6) d
Admire 2 F	62.0 (5.8) cd	58.3 (2.9) b	57.6 (3.2) bc	67.8 (5.4) bcd
Danitol 2.4 EC	95.0 (6.0) bc	59.1 (3.6) b	68.4 (6.1) bc	109.6 (7.8) b
Surround WP	91.0 (7.4) bc	66.9 (4.1) b	78.0 (8.7) b	93.9 (9.5) bc
Kocide 101 WP	108.0 (10.5) ab	103.7 (9.9) a	67.2 (4.1) bc	168.0 (20.2) a
Agrimek 0.15 EC & Oil	115.0 (9.4) ab	106.3 (8.0) a	126.0 (16.0) a	163.8 (15.1) a
Alliete WDG	93.0 (8.5) bc	132.9 (12.0) a		
Citrus Soluble Oil	104.7 (6.1) ab			
Micromite 80 WGS	115.0 (9.4) ab			
Acramite 50 ws	139.0 (9.1) a			
Micromite 80 WGS & Oil	135.0 (8.6) a			
Control (water)	122.0 (10.1) ab	123.4 (9.3) a	124.8 (17.3) a	173.2 (21.2) a

Means within each time of application followed by the same letter are not significantly different ($P = 0.05$).

TABLE 3. PERCENT MORTALITY OF *A. VAQUITARUM* FROM 8 TO 96 H AFTER EXPOSURE TO EACH PESTICIDE.

	Percent mortality						Abbott's Corrected	
Treatment	8 h	16 h	24 h	48 h	72 h	96 h	72 h	96 h
0 d after application								
Sevin80 WSP	23.5	82.5	98.0	100	100	100	100	100
Malathion 5 EC	6.3	36.3	76.3	100	100	100	100	100
Imidan 70 WSB	6.3	47.8	86.8	98.0	100	100	100	100
Admire 2 F	0	4.5	26.3	59.5	89.5	95.8	87.3	91.6
Danitol 2.4 EC	0	2.3	2.3	22.0	55.5	85.0	46.1	70.0
Surround WP	0	0	0	21.3	36.5	67.0	23.0	34.0
Kocide 101 WP	0	0	0	13.0	39.0	72.8	26.1	45.6
AllieteWDG	0	0	2.0	10.5	40.8	80.5	28.2	61.0
Agri-Mek 0.15 EC & Oil	0	0	0	6.3	27.5	58.3	12.1	16.6
Citrus Soluble Oil	0	2.0	2.0	2.0	13.3	61.0	0	22.0
Micromite 80 WGS & Oil	0	0	0	2.0	8.8	36.8	0	0
Micromite 80 WGS	0	0	0	6.5	8.5	40.5	0	0
Acramite 50 WS	0	0	0	2.0	4.3	27.8	0	0
Control	0	0	0	8.8	17.5	50.0	x	x
7 d after application								
Sevin80 WSP	9.8	71.5	93.8	100	100	100	100	100
Malathion 5 EC	9.8	58.8	84.5	100	100	100	100	100
Imidan70 WSB	0	52.3	84.8	100	100	100	100	100
Admire 2 F	0	6.8	26.8	76.3	98.3	100	97.9	100
Danitol 2.4 EC	0	0	5.3	56.3	96.0	98.3	95.0	97.1
Surround WP	0	0	0	27.8	54.5	71.5	43.3	51.5
Kocide 101 WP	0	0	2.3	17.8	42.0	46.0	27.7	8.0
Agri-Mek 0.15 EC & Oil	0	0	0	8.0	34.8	48.8	18.7	12.8
Alliete WDG	0	0	0	0	19.3	36.8	0	0
Control	0	0	0	5.8	19.8	41.3	x	x
14 d after application								
Sevin80 WSP	18.5	64.5	95.8	100	100	100	100	100
Malathion5 EC	0	31.5	60.8	100	100	100	100	100
Imidan 70 WSB	0	24.3	55.3	92.5	95.0	95.0	92.6	88.2
Admire 2F	0	8.5	30.0	73.5	100	100	100	100
Danitol 2.4 EC	0	0	4.3	56.3	88.0	95.0	82.2	88.2
Surround WP	0	0	0	28.8	53.8	73.3	31.6	36.7
Kocide 101 WP	0	0	2.5	17.0	59.0	83.3	39.3	60.4
Agri-Mek 0.15 EC & Oil	0	0	4.5	11.3	30.0	43.8	0	0
Control	0	0	0	9.3	32.5	57.8	x	x
21 d after application								
Sevin80 WSP	4.3	64.8	87.0	100	100	100	100	100
Malathion 5 EC	4.8	33.3	69.8	100	100	100	100	100
Imidan 70 WSB	0	27.3	52.5	79.3	93.3	100	92.2	100
Admire 2 F	0	14.3	21.3	69.3	82.8	98.0	80.0	68.8
Danitol 2.4 EC	0	2.3	7.0	40.5	58.3	75.0	51.5	60.9
Surround WP	0	0	2.5	39.3	57.3	88.3	50.4	81.7
Kocide 101 WP	0	0	0	16.8	35.3	53.0	24.8	26.6
Agri-Mek 0.15 EC & Oil	0	0	0	9.5	21.5	44.0	8.7	12.5
Control	0	0	2.3	9.0	14.0	36.0	x	x

Treatments with survival equal to the control were not tested the following week.

completion of the 96-h experiment. Exposure to Surround® WP, Kocide® 101 WP, and Aliette resulted in substantially higher *A. vaquitarum* mortality than that observed on the water control, while mortality on Agrimek® 0.15 EC + Citrus Soluble Oil was marginally higher than that on

the control. *Aprostocetus vaquitarum* exposed to Citrus Soluble Oil, Micromite® 80 WGS, Micromite® 80 WGS + Citrus Soluble Oil, and Acramite® 50 WS had mortality rates marginally lower than that observed on the control. These four treatments did not appear to have an effect on *A. vaquitarum* survival, thus these treatments were not subjected to testing two to four weeks after application. The results were similar when the pesticides were tested two weeks after pesticide application. Sevin® 80 WSP and Malathion 5 EC resulted in 10% mortality after 8 h and all *A. vaquitarum* were dead 48 h after exposure to Sevin® 80 WSP, Malathion 5 EC, and Imidan® 70 WSB. Admire® 2 F and Danitol® 2.4 EC resulted in 100 and 98% mortality, respectively, after 96 h. Substantial mortality (72%) was also observed on Surround® WP after 96 h. Females exposed to Kocide® 101 WP and Agrimek® 0.15 EC + Citrus Soluble Oil showed slightly higher mortality than those exposed to the water control while those exposed to Aliette had a mortality rate slightly less than the control. Testing three and four weeks after pesticide application yielded similar results to weeks one and two. Sevin® 80 WSP remained the most toxic followed by Malathion 5 EC, Imidan® 70 WSB, Admire® 2 F, Danitol® 2.4 EC, Surround® WP and Kocide® 101 WP (Table 3). The relative toxicity of the pesticides was strikingly consistent over the four week period. Mortality rates decreased slightly over the four weeks; however, the toxicity of each pesticide was generally preserved. Though the pesticide treated substrate was maintained out of doors, it was protected from sunlight and precipitation.

Effect of Residual Pesticide on Parasitism

Survival of *A. vaquitarum* was affected by Sevin® XLR and Imidan® 70 WSB applied to foliage in the field. Fewer adult *A. vaquitarum* emerged from *D. abbreviatus* eggs laid on foliage treated with Sevin® XLR (0.0) and Imidan® 70 WSB (2.3 ± 1.3) than emerged from the water treated control (17.9 ± 1.9) when host eggs were laid immediately following pesticide application ($F_{2,61}$ = 30.8, $P < 0.001$) (Table 4). The number of adults emerging from eggs laid one week after application was lower on the Sevin® XLR treated foliage than on foliage treated with either Imidan® 70 WSB or water ($F_{2,75}$ = 10.34, $P < 0.001$). The number of adult *A. vaquitarum* emerging from host eggs laid two weeks after pesticide application was not different among the treatments ($F_{2,76}$ = 0.54, P = 0.59). The number of *D. abbreviatus* larvae emerging from eggs laid immediately after pesticide application was higher on foliage treated with Imidan® 70 WSB than on either the Sevin® XLR or control treatment ($F_{2,61}$ = 23.9, $P <$ 0.001) (Table 4). There were no differences in the number of *D. abbreviatus* larvae emerging among the treatments from eggs laid one week ($F_{2,75}$ = 1.11, P = 0.33) or two weeks after pesticide application ($F_{2,76}$ = 0.94, P = 0.39).

Significantly more *A. vaquitarum* adults emerged from host eggs laid immediately after pesticide application on foliage treated with Micromite® 80 WGS or Acramite® 50 WS than from the control. Fewer *A. vaquitarum* emerged from foliage treated with Micromite® 80 WGS + Citrus Soluble Oil or Citrus Soluble Oil alone ($F_{4,133}$ = 29.3, $P < 0.001$) (Table 5). The number of *A. vaquitarum* emerging from host eggs laid on foliage treated one ($F_{4,145}$ = 13.9, $P < 0.001$) and two weeks ($F_{4,145}$ = 11.7, $P < 0.001$) earlier was not significantly different among Micromite® 80 WGS, Acramite® 50 WS, and the control, but significantly fewer adults emerged from foliage treated with either Micromite® 80 WGS + Citrus Soluble Oil or Citrus Soluble Oil alone. The number of neonate *D. abbreviatus* larvae emerging was lower on foliage treated with Citrus Soluble Oil than on

TABLE 4. MEAN NUMBER (± S.E.) OF ADULT *A. VAQUITARUM* AND NEONATE *D. ABBREVIATUS* EMERGING FROM *D. ABBREVIATUS* EGG MASSES LAID ON HOST PLANT MATERIAL TREATED WITH SEVIN XLR AND IMIDAN 70 WSB 0, 7, AND 14 D BEFORE OVIPOSITION.

Treatment	Mean number (± S.E.)		
	Day 0	Day 7	Day 14
		Adult *A. vaquitarum*	
Control (water)	17.9 (1.9) a	12.0 (1.9) a	15.6 (2.1) a
Sevin XLR	0.0 (0.0) b	2.1 (1.4) b	12.6 (2.3) a
lmidan7OWSB	2.3 (1.3) b	13.6 (1.6) a	13.7 (1.7) a
		Neonate *D. abbreviatus*	
Control (water)	0.6 (0.4) a	3.4 (2.3) a	0.6 (0.6) a
Sevin XLR	0.8 (0.5) a	4.3 (2.1) a	1.2 (0.6) a
lmidan7OWSB	29.6 (5.4) b	0.7 (0.3) a	2.6 (1.5) a

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

TABLE 5. MEAN NUMBER (± S.E.) OF ADULT *A. VAQUITARUM* AND NEONATE *D. ABBREVIATUS* EMERGING FROM *D. ABBREVIATUS* EGG MASSES LAID ON HOST PLANT MATERIAL TREATED WITH MICROMITE 80 WGS, ACRAMITE 50 WS, CITRUS SOLUBLE OIL, AND MICROMITE + CITRUS SOLUBLE OIL 0, 7, AND 14 D BEFORE OVIPOSITION.

Treatment	Mean number (± S.E.)		
	Day 0	Day 7	Day 14
		Adult *A. vaquitarum*	
Micromite 80 WGS	22.6 (1.9) a	19.4 (2.9) a	12.9 (1.3) a
Acramite 50 WS	24.8 (3.3) a	20.8 (2.6) a	12.8 (1.8) a
Control (water)	9.3 (1.6) b	20.5 (2.7) a	14.2 (1.9) a
Micromite 80 WGS + Oil	0.8 (0.6) c	3.7 (1.0) b	3.3 (0.7) b
Citrus Soluble Oil	2.1 (1.1) c	1.4 (0.4) b	6.2 (1.8) b
		Neonate *D. abbreviatus*	
Micromite 80 WGS	0.0 (0.0) a	0.9 (0.9) a	0.3 (0.3) a
Acramite 50 WS	1.4 (0.7) a	0.3 (0.2) a	2.7 (1.4) a
Control (water)	2.6 (1.3)a	4.5 (2.2) a	2.7 (1.4) a
Micromite 80 WGS+ Oil	0.0 (0.0) a	0.5 (0.5) a	0.0 (0.0) a
Citrus Soluble Oil	23.6 (3.4) b	14.1 (2.5) b	12.8 (2.8) b

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

any of the other treatments when eggs were laid immediately ($F_{4,133} = 40.5$, $P < 0.001$), one ($F_{4,145} = 13.9$, $P < 0.001$), or two weeks ($F_{4,145} = 11.7$, $P < 0.001$) after pesticide application (Table 5).

Micromite® 80 WGS Fecundity Trial

There were no differences between oviposition by females exposed to Micromite® 80 WGS (20.3 ± 3.3) and those exposed to a water control (17.0 ± 2.8) ($F_{1,38} = 0.21$, $P = 0.65$) (Table 6). After 48 h, 45.8% of *A. vaquitarum* eggs laid by females exposed to Micromite® 80 WGS reached the first instar while 64.9% of eggs laid by females exposed to a water control reached the first instar after 48 h. There was no difference in the number of new generation *A. vaquitarum* adults emerging between Micromite® 80 WGS treated females (13.4 ± 2.5) and those females exposed to a water control (11.2 ± 1.0) ($F_{1,56} = 0.34$, $P = 0.56$). The number of host *D. abbreviatus* eggs was not different between the treatments for either the dissected egg masses ($F_{1,38} = 0.98$, $P = 0.33$) or those reared to emergence ($F_{1,56} = 0.29$, $P = 0.59$).

TABLE 6. MEAN NUMBER OF EGGS, LARVAE, HOST EGGS, AND TOTAL OVIPOSITION (± S.E.) BY *A. VAQUITARUM* AFTER 72 H EXPOSURE TO MICROMITE 80 WGS AND TOTAL MEAN OFFSPRING AND HOST EGGS AVAILABLE (± S.E.) FOR *A. VAQUITARUM* OVIPOSITION ON THREE CONSECUTIVE DAYS.

Treatment	Control	Micromite 80 WGS
Eggs	6.0 (1.2) a	11.0 (1.8) a
Larvae	11.0 (1.9) a	9.3 (2.4) a
Total Oviposition	17.0 (2.8) a	20.3 (3.3) a
Host eggs	185.5 (15.6) a	168.5 (11.8) a
Adult Offspring	11.2 (1.0) a	13.4 (2.5) a
Host Eggs	167.9 (6.4) a	171.4 (7.8) a

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

DISCUSSION

The impact of the 12 pesticides tested against *A. vaquitarum* ranged from harmless to highly toxic. The most acutely toxic products tested were Sevin® 80 WSP (carbamate), Malathion, and Imidan® 70 WSB (organophosphates). When tested immediately after application, mortality was more than twice as rapid as the next most toxic pesticides. Admire® 2 F (neonicotinoid) and Danitol® 2.4 EC (pyrethroid) were also toxic to *A. vaquitarum*. These and many other neurotoxic insecticides used in citrus are known to be extremely detrimental to a range of hymenopteran parasitoids and other beneficial insects (Easwaramoorthy et al. 1990; Villanueva-Jiménez & Hoy 1998; Jacas & García-Marí 2001; Wakgari & Giliomee 2003; Michaud & Grant 2003), including *Aprostocetus ceroplastae* (Girault) (Wakgari & Giliomee 2001). The regular use of these products will impede the establishment and productivity of *A. vaquitarum* and almost certainly have a negative impact on various other beneficial insects.

Surround® WP (kaolin clay) is touted as nontoxic and IPM-compatible. Though not as toxic as the neurotoxic insecticides, Surround® WP increased mortality and reduced the longevity of *A. vaquitarum* compared to the control and the other less harmful pesticides tested. The cause of death was not clear in the present study, but cadavers

were often observed covered in kaolin particles. Application of Surround® WP to citrus has also been observed to increase scale insect infestations, most likely due to interference with parasitism (S. L. Lapointe, unpublished). The effect of Surround® WP in the present experiment may have been magnified by the exclusion of precipitation from the weathering process. Under these conditions, the Surround® WP residue would be expected to remain intact and not decline in potency.

Aprostocetus vaquitarum females exposed to Agrimek® 0.15 EC (avermectin), Kocide® 101 WP (copper hydroxide) and Aliette WDG showed a slight increase in mortality but longevity was not significantly different than that observed on the control. These products appear to be compatible with this parasitoid. However, at recommended rates Kocide® 101 WP and Agrimek® 0.15 EC were shown to be detrimental to *Ageniaspis citricola* (Logvinovskaya) (Hymenoptera: Encyrtidae), a parasitoid of the citrus leafminer (*Phyllocnistis citrella* (Stainton) (Lepidoptera: Gracillariidae) (Villanueva-Jiménez & Hoy 1998). Avermectin can affect citrus predatory mites negatively, including *Euseius stipulatus* (Athias-Henriot) (Jacas & García Marí 2001). Thus, further study of the effects on other beneficial insects in citrus is warranted.

Three of the products tested showed no contact toxicity to adult females, including Acramite® 50 WS, Micromite® 80 WGS, Citrus Soluble Oil, and Micromite® 80 WGS + Citrus Soluble Oil. Acramite® 50 WS (bifenazate) also has been shown to be compatible with the predatory mite *Phytoseiulus persimilis* (Kim & Yoo 2002) and only moderately harmful to ladybird beetles (James & Coyle 2001). Micromite® 80 WGS (diflubenzuron) is known to be toxic to several parasitoid species (Zaki & Gesraha 1987; Zijp & Blommers 2001; Amalin et al. 2004; Schneider et al. 2004), while it appears relatively harmless to others (Willrich & Boethel 2001; Amalin et al. 2004). Citrus Soluble Oil used alone is known to be compatible with other parasitoids and beneficial predators in citrus production (Amalin et al. 2000; Villanueva-Jiménez et al. 2000).

Results of the field studies were consistent with the laboratory tests. Sevin® XLR sprayed on host plant material was extremely toxic, resulting in no parasitoid reproduction when *D. abbreviatus* eggs were laid immediately after spraying, and continued to significantly reduce *A. vaquitarum* populations one week after application. It was not until 14 d after treatment that Sevin® XLR no longer had a significant impact on *A. vaquitarum*. Imidan® 70 WSB significantly reduced *A. vaquitarum* reproduction but lost efficacy more quickly than Sevin® XLR and no longer reduced *A. vaquitarum* reproduction after one week in the field. Very low numbers of neonate *D. abbreviatus* eclosed on the control, due to high levels of parasitism, or on foliage treated with Sevin® XLR, due to its toxicity to both the parasitoid and the pest. However, treatment with Imidan® 70 WSB resulted in high mortality of the beneficial but not *D. abbreviatus*. Though Imidan® 70 WSB broke down relatively quickly in the field, its negative impact on *A. vaquitarum* and minimal effect on *D. abbreviatus* make it a very poor candidate for an IPM program.

Insect growth regulators such as Micromite® 80 WGS (diflubenzuron) have generally been considered environmentally safer alternatives to broad-spectrum insecticides. Diflubenzuron has been shown to have a minimal impact on some hymenopteran parasitoids (Villanueva-Jiménez & Hoy 1998; Willrich & Boethel 2001; Amalin et al. 2004). However, it is known to have devastating effects on other parasitoid species (Zaki & Gesraha 1987; Zijp & Blommers 2001; Amalin et al. 2004; Schneider et al. 2004). Many pesticide toxicity tests are carried out on only one developmental stage of the parasitoid, usually the adults, but Schneider et al. (2003a, 2003b) showed that diflubenzuron can have detrimental effects on developmental processes while appearing relatively harmless to adult parasitoids. In the present study, Micromite® 80 WGS was not toxic to adult *A. vaquitarum* but was further tested under field conditions and in the laboratory to assess oviposition and development from egg to adult. Consistent with the contact toxicity test with adult females, Micromite® 80 WGS had no negative affect on *A. vaquitarum* when host eggs were laid on field treated host plants and tested 0 to 14 d after application. Oviposition by females exposed to Micromite® 80 WGS in the laboratory was not significantly different from the control, though there was an indication that the time from oviposition to first-instar eclosure may be extended for eggs laid by Micromite® 80 WGS exposed females. If detrimental, diflubenzuron, a chitin synthesis inhibitor, often inhibits egg hatch and disrupts the molting process (Marx 1977; Weiland et al. 2002). In the present study there were no apparent differences in development from egg to adult between the Micromite® 80 WGS treatment and the water control.

Micromite® 80 WGS (diflubenzuron) is effective in reducing *D. abbreviatus* populations (Schroeder 1996) and had no affect on *A. vaquitarum* in the present study. Micromite® 80 WGS use appears to be compatible with both *A. vaquitarum* and *Quadrastichus haitiensis* (Gahan) (Amalin et al. 2004), two of the primary parasitoids of *D. abbreviatus* now established in south Florida. Diflubenzuron was also considered harmless for citrus predatory mites (Jacas & García Marí 2001). However, diflubenzuron was shown to adversely affect *Ceratogramma eteinnei* (Delvare) (Amalin et al. 2004), an endoparasitoid of *D. abbreviatus* which was released and failed to

establish in south Florida, as well as several other hymenopteran parasitoids (Zaki & Gesraha 1987; Zijp & Blommers 2001; Amalin et al. 2004; Schneider et al. 2004). Its impact on the agroecosystem merits further study.

Though Micromite® 80 WGS alone had no negative impact on *A. vaquitarum*, Micromite® 80 WGS + Citrus Soluble Oil and Citrus Soluble Oil alone did significantly reduce *A. vaquitarum* reproduction. It appears that the *D. abbreviatus* egg masses laid between leaves treated with Citrus Soluble Oil do not remain closed and become exposed to the elements. *Aprostocetus vaquitarum* will not oviposit into an exposed egg mass and if oviposition occurs before the egg mass opens, parasitoid eggs and larvae desiccate and die when the egg mass opens (J. E. Peña, unpublished). Though Citrus Soluble Oil does not appear to be toxic to *A. vaquitarum*, it does indirectly affect this parasitoid by reducing the efficiency of the adhesive *D. abbreviatus* uses to secure and protect its eggs between two leaves. Citrus Soluble Oil treatments had a negative affect on *C. eteinnei* (Amalin et al. 2004). *Aprostocetus vaquitarum*, an ecto-parasitoid, is extremely vulnerable to the environment and possibly even more severely impacted when the host egg mass is opened and exposed.

The aim of this study was to evaluate the relative toxicity of citrus pesticides in an effort to promote the use of compounds with low toxicity levels to *A. vaquitarum* and other beneficial insects. At recommended rates, Sevin® 80 WSP, Malathion 5 EC, and Imidan® 70 WSB, were extremely toxic to *A. vaquitarum* and will discourage the establishment of this insect. Admire® 2F, Danitol® 2.4 EC, and Surround® WP were also moderately toxic to *A. vaquitarum* and regular use would be detrimental to a control program aimed at establishing and maintaining this parasitoid. Kocide® 101 WP, Aliette WDG, and Agrimek® 0.15 EC + Citrus Soluble Oil were relatively non-toxic. Micromite® 80 WGS, Acramite® 50 WS, and Citrus Soluble Oil were nontoxic to *A. vaquitarum* adults and these products appear to be very suitable for an IPM program. Micromite® 80 WGS was also shown not to disrupt development of *A. vaquitarum* while Citrus Soluble Oil, though not toxic, did reduce the success of *A. vaquitarum* by causing host egg masses to become exposed. Given the restricted field evaluations conducted in the present study, further research should focus on the impact of these pesticides under field conditions.

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VERSATILITY OF BAITS CONTAINING NOVIFLUMURON FOR CONTROL OF STRUCTURAL INFESTATIONS OF FORMOSAN SUBTERRANEAN TERMITES (ISOPTERA: RHINOTERMITIDAE)

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ABSTRACT

Four buildings (two high-rise condominiums, a single-family residential structure, and a trailer) in Broward and Miami-Dade Counties, Florida, infested with Formosan subterranean termites (FST, *Coptotermes fomosanus* Shiraki) were treated with baits containing 0.5% wt/wt noviflumuron. Each building represented a challenging treatment scenario for liquid termiticides due to the location of the infestation within the structure and/or occupant refusal to permit pesticide application in termite-infested living and activity areas. Marking of FST by in-situ baiting with blank bait matrix treated with 0.5% wt/wt Neutral Red dye indicated only one FST foraging population infested each building. Two FST infestations were aerial in high-rise condominiums. Noviflumuron baits were applied to two buildings in aboveground stations, one building with in-ground stations, and the remaining building with both station types. All detected FST infestations were eliminated within 71-92 days after first application of noviflumuron baits. FST foraging populations with confirmed ground contact consumed approximately 4-fold more bait than did aerial infestations; mean ± SD, 242 ± 74 g vs. 62 ± 51 g, respectively. Termite feeding activity was monitored before, during, and after bait application at two buildings with an acoustic emissions detector (AED) and in one building with a microwave detector. Cessation of termite activity measured with these devices corresponded with elimination of live FST previously observed in stations, infested wood, and foraging tubes. No FST were observed in any monitoring station or building during the 12-18 month inspection period following elimination of the detected FST infestation.

Key Words: Sentricon™ System, Recruit™ termite bait, noviflumuron, chitin synthesis inhibitor, *Coptotermes formosanus*

RESUMEN

Cuatro edificios (dos condominios altos, una estructura residencial para una sola familia, y una casa trailer en los Condados de Broward y de Miami-Dade, Florida, infestadas con la termita subterranea de Formosa (FST, *Coptotermes fomosanus* Shiraki) fueron tratadas con cebos que contienen 0.5% peso/peso de noviflumuron. Cada edificio representó un desafio para el tratamiento con los termiticidas liquidos debido al lugar de la infestación dentro la estructura y/o el rechazo del occupante para permitir la aplicación de un pesticida en áreas infestadas de sus hogares donde ellos tienen sus actividades. Al marcar los FST in-situ con una matriz de cebo vacio tratado con 0.5% peso/peso de tinta Roja Neutral indico una sola población de FST forrajera infestando cada edificio. Dos infestaciones áereas de FST fueron presentes en los condominios. Se aplicaron cebos de Noviflumuron en puestos encima de la superficie en dos edificios, en puestos subterraneos en un edificio, y en puestos de las dos clases en los otros edificios. Todas las infestaciones de FST detectadas fueron eliminadas dentro de 71-92 dias después de la primera aplicación de los cebos de Noviflumuron. Las poblaciones forrajeras de FST con contacto confirmado con la tierra consumieron aproximadamente 4 veces mas cebo que las infestaciones áereas; con un promedio ± DS de 242 ± 74 g vs. 62 ± 51 g, respectivemente. Se realizó un monitoreo de la actividad de la alimentación de las termitas antes, durante y después de la aplicación de cebo en dos edificios con un detector de emissiones acústico (AED) y en un edificio con un detector de microhonda. La paralización de la actividad de las termitas medida con estos aparatos correspondia con la eliminación de los FST vivos observados anteriormente en los puestos de estudio, madera infestada, y en los tubos de forrajeo. Ningun FST fue observada en cualquier puesto o edificio durante el periodo de inspección de 12-18 meses después de la eliminación de la infestación detectada de FST.

Hexaflumuron, a chitin synthesis inhibitor, was documented in the late 1980s to cause ecdysis inhibition resulting in delayed mortality in *Reticulitermes flavipes* (Kollar) and *Coptotermes formosanus* Shiraki (Su & Scheffrahn 1993). Since that discovery, many field studies have ver-

ified that termite baits containing hexaflumuron eliminated colonies or populations of 15 species of subterranean termites in 15 states in the US, and in Australia, Japan, Malaysia, Taiwan, France, England, Italy, Cayman Islands, Puerto Rico, and US Virgin Islands (Lee 2002; Sajap et al. 2002; Su 2002a, b; Su et al. 2002; Su et al. 2003; Su & Hsu 2003).

In 1995, Dow AgroSciences developed the chitin synthesis inhibitor, noviflumuron, and began trials to assess its toxicity against common household and structural pests, including subterranean termites (Smith et al. 2001). In laboratory trials in which *R. flavipes* were fed radiolabeled noviflumuron or hexaflumuron, noviflumuron demonstrated significantly faster speed of action, greater potency, and nearly 4-fold slower clearance from termites compared with that of hexaflumuron (Sheets et al. 2000; Karr et al. 2004). In field trials conducted throughout the US from 1998-2000, 74 colonies of *Reticulitermes* spp. baited with noviflumuron were eliminated in about half the time as the 53 colonies baited with hexaflumuron (mean = 107 days vs. 205 days, respectively, Smith et al. 2001). Sajap et al. (2005) eliminated five structural infestations of *Coptotermes gestroi* (Wasmann) within 35-56 d with aboveground (AG) baits containing 0.5% noviflumuron.

The purpose of the trials described in this study was to determine if bait containing 0.5% noviflumuron could eliminate structural infestations of FST. Although not a selection factor, each building in this study represented a challenging treatment scenario for liquid termiticides due to the location of the infestation within the structure (dispersed in the upper story of high-rise condominiums or in a difficult to access crawlspace) and/or occupant refusal to permit pesticide application in critical areas.

Materials and Methods

Termite Bait/Monitoring Stations

In-ground (IG) or AG stations used in the Sentricon System (Dow AgroSciences, Indianapolis, IN) were used to monitor termite activity and apply noviflumuron baits. IG stations, as described by Su et al. (2002), contained monitoring devices (two 1.4 × 2.8 × 17.5 cm wood slats, Fig. 1) when first installed. To apply the bait, the wood monitoring devices were replaced by a bait tube containing 0.5% wt/wt noviflumuron on a 35-g roll of textured laminated cellulose.

An AG station consisted of a rigid, rectangular plastic housing (14.8 cm long × 9 cm wide × 5 cm deep) containing two 35-g laminated textured cellulose rolls (Fig. 2). One side of the housing was open to expose the matrix to the termite-infested substrate; the other side was closed by a removable lid. Blank bait containing no active ingredient was used to monitor termite activity in both IG and AG stations.

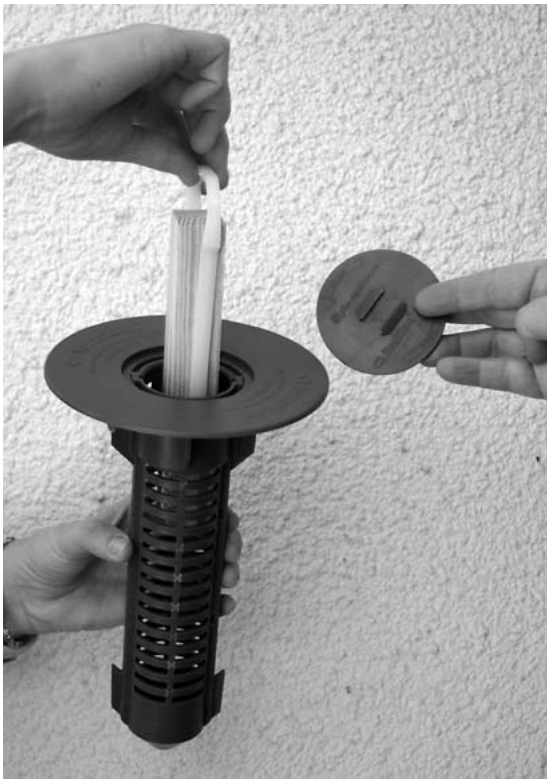

Fig. 1. In-ground (IG) station for applying wood monitoring devices (shown here) or bait tube containing 35-g roll of laminated cellulose matrix; blank or impregnated with 0.5% wt/wt noviflumuron.

Study Sites

Noviflumuron baits were evaluated at three buildings in Broward County and one in Miami-Dade County, FL that had active subterranean termite infestations. Soldiers and/or alates were collected and identified as FST with the key by Scheffrahn (1994).

DAYCARE was a 195.2-m^2, single-story, concrete block, slab-on-grade house in Hollywood Hills, FL, converted to a daycare center for infants and preschool children. In mid-May, 2001, daycare employees reported that massive emergence of FST alates forced them to evacuate the daycare center and relocate the children. Subsequently, on 18 May, 2001, the first author found live FST in a backyard mango tree (Fig. 3) and in the garage in an aerial carton nest located between pieces of plywood propped over the expansion joint abutting the house slab. The nest was removed to expose many FST mud foraging tubes emerging from the expansion joint. FST damage,

Fig. 2. Slicing bait of aboveground (AG) station containing two 35-g rolls of laminated cellulose matrix; blank or impregnated with 0.5% wt/wt noviflumuron.

including alate release slits, was found on the garage rear entrance doorframe and the nearby exposed header in the breezeway (Fig. 3). DAYCARE had not been treated with liquid termiticides due in part to concerns of the staff about pesticide exposure.

TRAILER was a small, wood frame, 40-m^2 trailer with aluminum siding and a crawlspace. A 33.2-m^2 addition consisting of three rooms (storage, sewing, and entry area) and a porch on a raised concrete slab were attached to the trailer (Fig 4). According to detailed records maintained by the owner, FST alate flights occurred in the front rooms or bedroom between approximately 6:00 pm and 12:30 am on 48 different days from May 27 through August 1, 2002. On June 5, 2002, a pest control company applied Premise™ termiticide, containing 0.05% imidacloprid (Bayer Environmental Science, Montvale, NJ), around the trailer perimeter and in the crawlspace according to the company service report and owner observations. No evidence was found that the hollow block foundation supporting the raised concrete slab was drilled and treated with termiticide. Access to this foundation through the crawlspace was very restricted. During an inspection on June 28, 2002, the first author found dead FST alates in the bedroom and storage room, and FST alate release slits in the wall paneling of the bedroom and living room (Fig. 4). No evidence of live FST was found in the crawlspace.

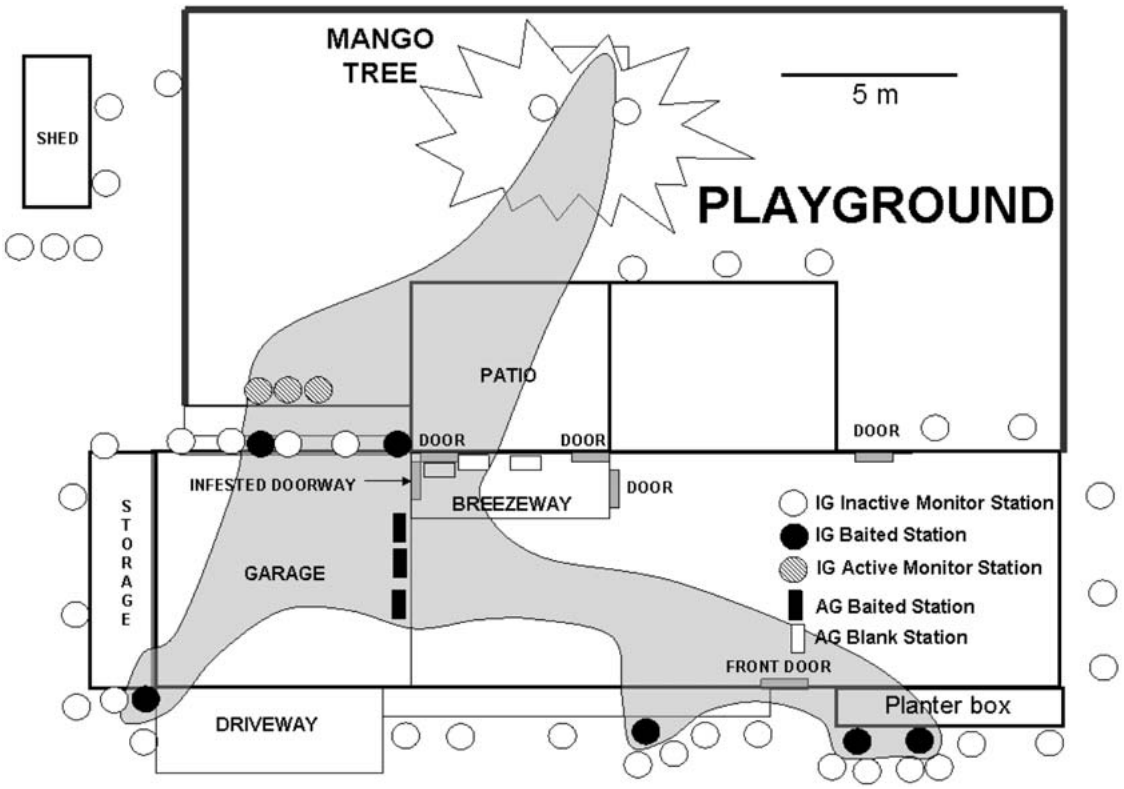

Fig. 3. Ground plan of DAYCARE showing placement of in-ground and aboveground stations and 0.5% noviflumuron bait. Gray shaded area indicates population foraging area based on presence of termites in the mango tree, dyed termites in bait stations, and AED readings.

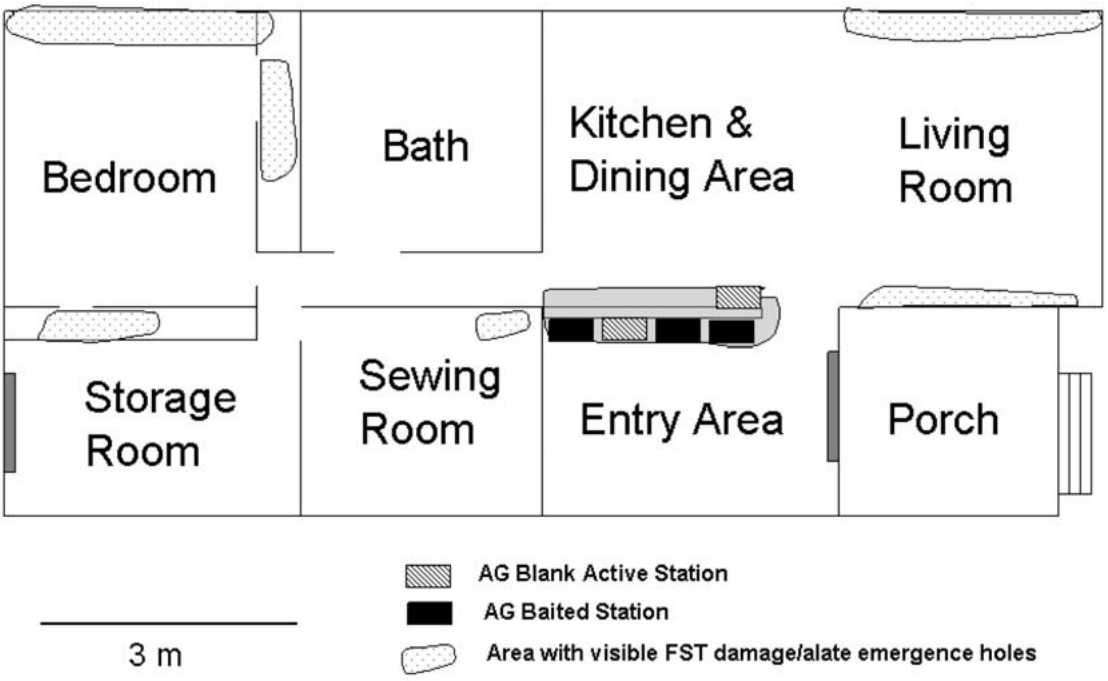

Fig. 4. Floor plan of TRAILER showing placement of aboveground stations after inspection on October 25, 2002, 0.5% noviflumuron bait, and areas damaged by Formosan subterranean termites. Gray shaded area indicates population foraging area based on presence of dyed termites in bait stations.

CONDO was an eight-story, reinforced concrete, multi-unit residential building in Hallandale, FL. On April 19, 2002, the first author found FST infesting extensive foraging tubes extending up the west stairwell onto the 8th floor landing and attic. There was no evidence of termite damage or activity on the ground floor or around the building perimeter. In mid-May, 2002, a husband and wife reported FST infesting their 8th floor condominium adjacent to the west stairwell. Because the wife was 6-mo pregnant and her infirm mother was about to be moved into their condominium, the occupants would not permit any pesticide application inside their condominium. Subsequently, on May 30, 2002, in this condominium the authors found termite damage and carton material in the doorframes of the two bathrooms and the second bedroom and in the master bedroom closet wall next to the west stairwell, where termites remained active (Fig. 5).

PENTHOUSE was a 29-story, reinforced concrete, multi-unit residential building in Aventura, FL. On November 1, 2002, the first author found live FST infesting a palm tree stump and in the soil around the base of another palm stump inside a planter, and in foraging tubes and several joists on the underside of the raised, wood patio deck (Fig. 6). No termite damage was reported by any other occupants or found indoors in the rooms directly below the infested patio. FST have been documented previously to establish aerial infestations on flat rooftops of high-rise buildings similar to CONDO and PENTHOUSE (Su et al. 1989; Weissling & Thoms 1999).

Installation of Monitoring Stations

In-ground (IG) stations were installed following the label directions for Recruit II™ termite bait. Stations were installed around the perimeter of DAYCARE (Fig. 3) and TRAILER (Fig. 4) more than 45 cm from the foundation to avoid placement in soil previously treated with termiticide. Spacing between stations did not exceed 6 m where soil access was not restricted by driveways and concrete patios (Fig. 3). Stations also were installed adjacent to areas with visible termite activity, such as in the rooftop planter box of PENTHOUSE (Fig. 6). After initial IG station installation, one or two "auxiliary" IG stations were installed within 30 cm of each IG station with termite activity if space permitted.

Aboveground (AG) stations containing blank bait rolls were installed where live FST were visible in surface foraging tubes (DAYCARE expansion joint, CONDO stairwell, and PENTHOUSE deck joist) and damaged wood (TRAILER partition wall and PENTHOUSE palm stump, Figs. 3-6). AG stations were installed adjacent to where acoustic emissions detector (AED) counts indi-

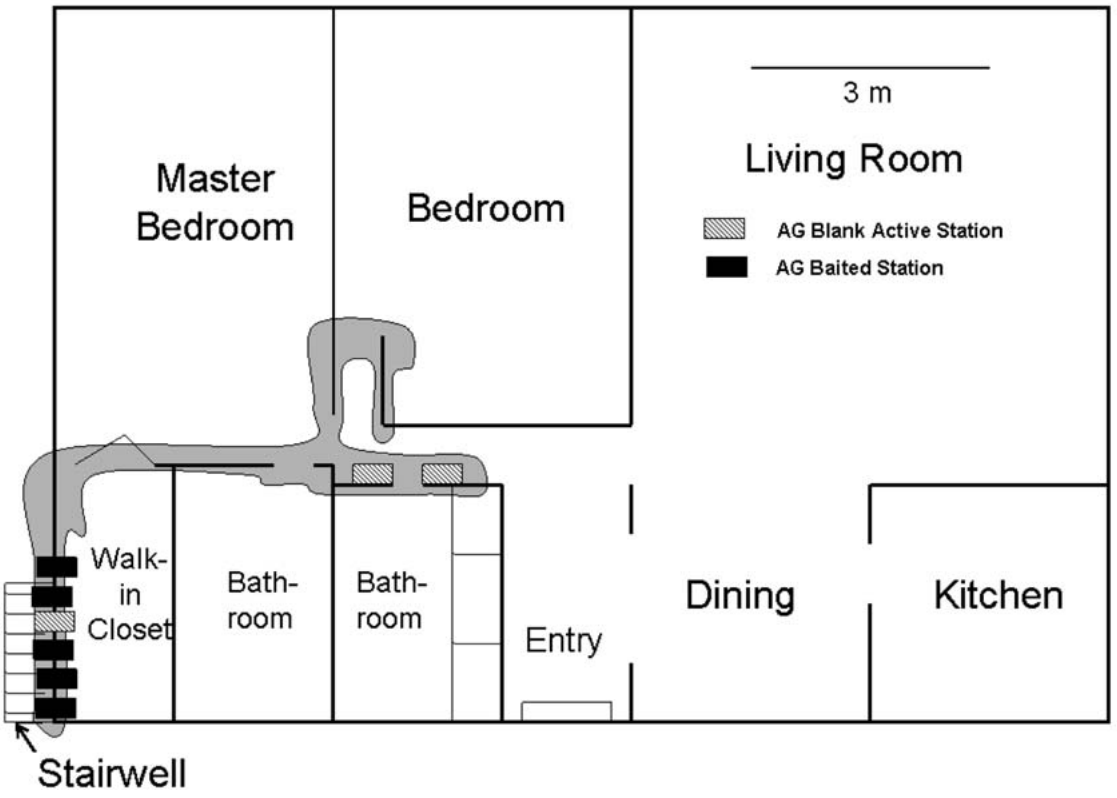

Fig. 5. Floor plan of CONDO showing placement of in-ground and aboveground stations, 0.5% noviflumuron bait, and area monitored with an acoustic emissions detector. Gray shaded area indicates population foraging area based on presence of dyed termites in bait stations and AED readings.

cated termite feeding but FST were not visible (DAYCARE breezeway header and CONDO door frames). In these locations, 2-mm diam holes were drilled into the wood before attaching each AG station to provide the termites access to the bait.

Each AG bait roll was sliced several times longitudinally (Fig. 2) and then moistened with 30-60 ml of water (DAYCARE), 5% sucrose water solution (CONDO, PENTHOUSE, TRAILER), or sports drink (TRAILER; Gatorade™, Gatorade Corp., Chicago, IL). The sliced bait rolls were placed directly in contact with the FST-infested surface. The station housing was attached to the surface with screws for wood surfaces and latex caulk (Polyseamseal™, OSI, Mentor, OH). The removable lid was sealed to the housing with screws and masking tape. All IG and AG stations were numbered and their locations were documented on site maps.

Use of Electronic Termite Detection Devices

At DAYCARE and CONDO, an Acoustic Emission Detector (AED, Locator™ Insect Detection Device, Dow AgroSciences, Indianapolis, IN) was used to monitor FST feeding activity in exposed wood. The AED has been documented to be a simple, non-disruptive method to quantify subterranean termite feeding activity (Scheffrahn et al. 1993) before and after application of termite baits (Su et al. 2000; Su et al. 2002; Su et al. 2003; Weissling & Thoms 1999).

Thirteen locations on one doorframe and the breezeway header at DAYCARE (Fig. 3) and 27 locations on three doorframes at CONDO (Fig. 5) were monitored with an AED. The sensors were attached by putty (Handitak™, SuperGlue Corp., Hollis, NY) to monitored wood members. Each AED location was marked and monitored once for 30 s in the noise reduction setting during each visit before, during, and after bait application. Based on user experience, readings of less than 5 counts usually do not indicate termite activity. Readings were repeated if sensor movement or detachment occurred. The last AED monitoring was conducted at 16.5 mo (DAYCARE) and 1 mo (CONDO) after elimination of all detectable FST activity. Acoustic detection was not continued at CONDO because damaged doorframes were replaced by the condominium owners after elimination of all detectable FST activity.

A microwave detector (TermaTrac™ Archerfield, Queensland, Australia) was used to detect

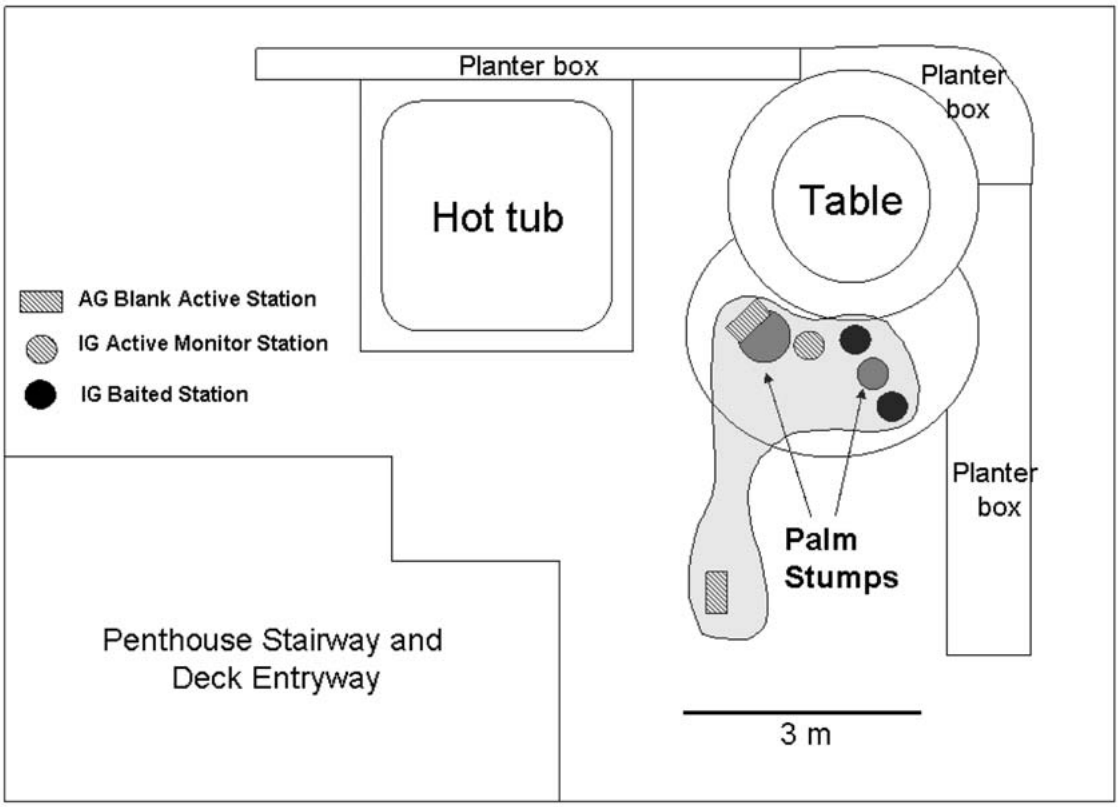

Fig. 6. Floor plan of PENTHOUSE showing placement of in-ground and aboveground stations and 0.5% noviflumuron bait. Gray shaded area indicates population foraging area based on presence of dyed termites in bait stations.

FST activity at TRAILER. Evans (2002) verified that the TermaTrac had a 90% success rate for detecting subterranean termites. The detector was used to locate FST in and near areas of the wall and floor of the trailer with visible termite damage. For wall paneling, the sensor horn was held flush against the surface while taking readings for 30 to 60 s. On the floor, the horn was placed upright directly on the surface for the same amount of time. The detector was used again on the same areas of the floor one year after elimination.

Bait tube Installation in IG Stations

At least 20 ml of water was used to moisten the matrix (blank, dyed or with noviflumuron) in a bait tube before installation. Termites from infested wood monitors or bait tube were gently transferred to the chamber in the top of the bait tube. The new bait tube was placed in the same station from which the termites were extracted.

Replenishment of AG Stations

Dry AG bait was remoistened with 30-60 ml of water on subsequent inspections after installation. If one third to one half of the matrix was consumed, one additional AG station with moistened matrix (blank, dyed or with noviflumuron) could be attached on top of the existing station with screws and masking tape.

Delineating Termite Populations with Dye Markers

When live termites were found in two or more IG and/or AG stations at a test site, the bait dyed with a 0.5% wt/wt Neutral Red in a bait tube or AG station was installed as previously described. On subsequent inspections, stations containing dyed termites were documented, classified as being connected, and the termites were considered to be from the same foraging population. Dyed matrix was introduced into additional stations containing dyed termites if the intensity of the color in dyed termites or the number of dyed termites was very low.

Application of Noviflumuron Baits

Application of noviflumuron bait began when two or more IG and/or AG stations with live termites were found to be connected based upon the

dye marker. Noviflumuron baits were not applied in at least one connected station with live termites at each site to provide an independent monitor for termite activity. Only blank baits were applied in FST-infested stations located within the children's play yard and breezeway at DAYCARE (Fig. 3) and in the condominium at CONDO (Fig. 5), due to occupants' requests not to have pesticides applied in these areas. By three mo after termite activity had ceased in all stations and in previously detected infested locations within a building, all noviflumuron baits were replaced with wood monitors in IG stations and blank bait in AG stations.

Station Inspections

Stations were inspected approximately every 1-4 weeks before and during application of noviflumuron. Wood monitors or baits that were moldy, degraded, or more than 50% consumed were replaced. The station type (IG or AG), type of device in station (monitor, dye, active ingredient), station device action (new, inspected, or replaced), estimated consumption of device, presence or absence of termites, presence of dyed termites, and estimated number of termites were recorded. The amount of wood and bait consumed was calculated by multiplying the total estimated percentage of the device consumed by the known mean, dry weight of whole devices: 62 g for wood monitor, 35 g for IG bait roll and 70 g for AG bait roll (Tables 1 and 2; DeMark & Thomas 2000; Weissling & Thoms 1999).

Stations were inspected approximately every 3 mo for at least one year following removal of all noviflumuron bait. During the final site inspection, the previously infested building or condominium unit and landscape features, such as the mango tree at DAYCARE, were visually inspected for evidence of any new termite activity.

Results and Discussion

Dye marking indicated only one FST foraging population infested each building. Dyed termites were found in all IG and AG stations with termite activity at each site. The cessation of termite activity detected in foraging tubes, infested wood, and by electronic monitoring following application of noviflumuron in stations where dyed termites were found further indicate only one FST foraging population infested each building. Husseneder et al. (2003) demonstrated FST in New Orleans collected within a foraging territory delineated by mark-recapture were genetically similar and could be genetically differentiated from termites in adjacent territories.

Stations were rapidly infested by FST, so baiting with noviflumuron began within 2-6 weeks after station installation, except at TRAILER. At this site, 22 IG stations were installed on July 8, 2002, 17 IG stations were installed on July 26, 2002 along the sides of two neighboring trailers, and three AG stations containing blank bait were installed in the bedroom on August 2, 2002. These stations were inspected through September 30, 2002, but no FST activity was detected in any station. On October 2, 2002, the first author conducted a thorough structural inspection, including the crawlspace, with a flashlight, probing tool, and the Termatrac™, but no FST were seen or detected. Subsequently, all stations were removed from TRAILER.

At the request of the property owner, the first author visually re-inspected TRAILER on October 25, 2002. Live FST were found in a low-rise, wood-paneled partition separating the kitchen and entry areas (Fig. 4) along the juncture of the trailer and raised slab addition. The termites were likely entering through the hollow blocks of the stem wall of the raised slab. AG stations containing blank bait moistened with sucrose solu-

Table 1. Summary of baiting with inground (IG) and aboveground (AG) stations containing 0.5% noviflumuron to control Formosan subterranean termites (FST) infesting four buildings in Broward and Miami-Dade counties, Florida, 2001-2003.

Site	Date monitor stations installed	Date 1st bait applied	Date detected FST infestation eliminated	Days to eliminate	Total estimated g dry wt bait matrix consumed	Total estimated mg AI consumed	Total # noviflumuron bait devices installed[2]	Days post-elimination final inspection[1]
DAYCARE	6/29/01	7/13/01	10/05/01	82	294	147	15IG, 6AG	499
TRAILER	7/08/02	2/21/03	5/02/03	71	189	95	6 AG	364
CONDO	5/30/02	6/28/02	9/30/02	92	98	49	6 AG	549
PENTHOUSE	11/27/03	1/13/03	3/26/03	73	26	13	4 IG	373

[1]Inspection of all monitoring stations and building

[2]Numbers of noviflumuron bait devices installed are greater than number of baited IG and AG stations indicated in Fig 3-6 because noviflumuron baits were replaced as required if consumed or degraded in IG and AG stations.

TABLE 2. TOTAL ESTIMATED NUMBER OF FORMOSAN SUBTERRANEAN TERMITES (FST) AND ESTIMATED G MATRIX CONSUMED BY DEVICE TYPE (BLANK MONITOR OR 0.5% NOVIFLUMURON BAIT), MONTH OF BAIT APPLICATION, AND STUDY SITE IN BROWARD AND MIAMI-DADE COUNTIES, FLORIDA, 2001-2003.[1]

Site (station type[2])	Type of matrix[3]	Initial noviflumuron application		1st Month		2nd Month		3rd Month	
		# FST (*n*)[4]	Total g (*n*)[5]	# FST (*n*)	Total g (*n*)	# FST (*n*)	Total g (*n*)	# FST (*n*)	Total g (*n*)
DAYCARE (IG & AG)	Blank	970 (10)	266 (8)	1570 (8)	85 (6)	100 (1)	231 (5)	0	0
	0.5% AI	—	—	175 (4)	28 (3)	700 (4)	247 (7)	129 (3)	19 (1)
TRAILER (AG)	Blank	183 (4)	172 (4)	1210 (5)	151 (5)	400 (2)	105 (3)	2 (1)	11 (3)
	0.5% AI	—	—	670 (3)	175 (3)	50 (1)	14 (2)	0	0
CONDO (AG)	Blank	1595 (7)	221 (7)	420 (3)	35 (2)	200 (1)	14 (1)	0	0
	0.5% AI	—	—	500 (4)	98 (5)	7 (3)	0	0	0
PENTHOUSE (IG & AG)	Blank	525 (5)	265 (5)	560 (3)	114 (5)	1280 (4)	168 (4)	0	14 (1)
	0.5% AI	—	—	55 (2)	26 (2)	0	0	0	0

[1]No termites or matrix consumption observed at any site after 3rd month.
[2]IG = inground station, AG = aboveground station.
[3]Blank = IG wood monitoring device (62 g), blank IG bait (35 g), or blank AG bait (70 g). 0.5% AI (noviflumuron) = IG bait (35 g) or AG bait (70 g).
[4]*n* = total number of stations with live termites by inspection period.
[5]*n* = total number of stations with matrix consumption by inspection period.

tion were installed over live FST on this partition wall on November 8, 2002. Termites did not consume any of the bait through January 2003. Blank bait was then moistened with a sports drink on January 24, 2003 and two weeks later, termites were found actively consuming the bait.

The previous termiticide application and excessive wood decay in the trailer may have interfered with FST foraging and feeding on IG and AG stations. The untreated soil under the slab in the attached addition appeared to be the refugia for the remaining FST infestation. FST workers contacting the imidacloprid perimeter treatment may have suffered lethal and sublethal effects, preventing them from foraging in IG stations. The trailer frame was damp and decayed as a consequence of flooding several years before. Certain species of wood-decay fungi have been shown to make some wood species more palatable to *C. formosanus* than non-decayed wood (Cornelius et al. 2003; Cornelius et al. 2004). The combination of high wood moisture and fungal decay may have made the wood more palatable to the termites than the bait matrix until the sports drink was added. Although this observation suggests this product is a feeding stimulant, Cornelius (2005) found no significant feeding preferences by *C. formosanus* workers when offered filter paper disks soaked with water or Gatorade.

Detected FST infestations were eliminated in 71 to 92 days (mean ± SD = 80 ± 10 days) at all buildings after first application of noviflumuron bait (Table 1). The date of elimination was determined by cessation of all termite activity in IG and AG stations, previously infested foraging tubes and wood, and in electronically monitored locations. There were some aberrant AED readings at CONDO when monitored on September 6 and September 30. Four exceptionally high AE counts (69, 171, 240, and 602) recorded from two of the doorways on September 6, 2002 appear to have been anomalies possibly due to a malfunction with the equipment and were excluded from the mean counts for this date (Fig. 8). On that day, 75 dead soldiers were found in one AG station inside CONDO. On a previous inspection on August 29 of AG stations in the stairwell, only 7 live termites, all soldiers, were found. The absence of workers and presence of only soldiers are two indicators of a termite population in decline after workers have fed on noviflumuron bait. A single high reading (18 counts) recorded on September 30 inside the condo appeared to be aberrant based on the absence of termites in stations. September 30, 2002 was determined to be the date for elimination of the detected FST infestation because no consumption of AG bait occurred since the previous inspection and no live termites were observed. The lack of AE counts on October 25 2002, the subsequent absence of termites in damaged wood removed by the tenants, and lack of FST activity in AG stations through the following 18 mo until the final structural inspection further indicate this FST infestation was eliminated.

Ground-based FST foraging populations at DAYCARE and TRAILER ate approximately 4-fold more bait matrix with noviflumuron compared with that eaten by aerial populations at CONDO and PENTHOUSE (mean ± SD; 242 ± 74 vs. 62 ± 51 g, respectively). Weissling & Thoms (1999) also found a ground-based FST colony consumed, on average, 2.5-fold more termite bait than two aerial FST colonies. This may be due to differences in foraging population size. It has been observed that the availability of food and water can be limited for aerial termite colonies (Su et al. 1997, 2001) which could restrict population growth. Although we did not estimate the population size, the furthest distances between detected foraging locations were less for rooftop infestations at PENTHOUSE (6 m) and CONDO (9 m) than for DAYCARE (20 m).

No re-infestation by FST was found in any building or monitoring station during the remaining evaluation period following elimination of FST activity. The final inspection of stations and buildings occurred 12-18 mo after FST elimination (Table 1). During final inspections, no live termites were found in any station, building, or previously infested landscape feature, such as the mango tree at DAYCARE. No consumption of termite monitors in stations or new termite damage or signs of recent termite activity, such as foraging tubes, were found.

Results indicate 0.5% noviflumuron is not a feeding deterrent to FST. At DAYCARE during the third and final month of bait application, live termites and matrix consumption were observed only in noviflumuron baits, not in blank baits or wood monitors (Table 2). In addition, AED monitoring detected no termite feeding activity after August 15, 2001 during the second month of bait application (Fig. 7). Live termites and consumption were observed in monitoring stations containing blank monitors, but not noviflumuron, during the second and third month after initial application of noviflumuron at PENTHOUSE. The reason for this is during the second month of noviflumuron bait application, the owner relandscaped the planter bed removing the palm stumps with AG stations and all but one noviflumuron-baited IG station. The stacked AG stations attached to the wood decking were not disturbed. New IG stations containing wood monitors were subsequently installed, but no further termite activity was observed in any IG station. Despite this disruption in the bait application process, the detected FST infestation was eliminated at PENTHOUSE.

This study demonstrates the versatility of cellulose baits containing 0.5% noviflumuron for eliminating structural infestations of FST. Novi-

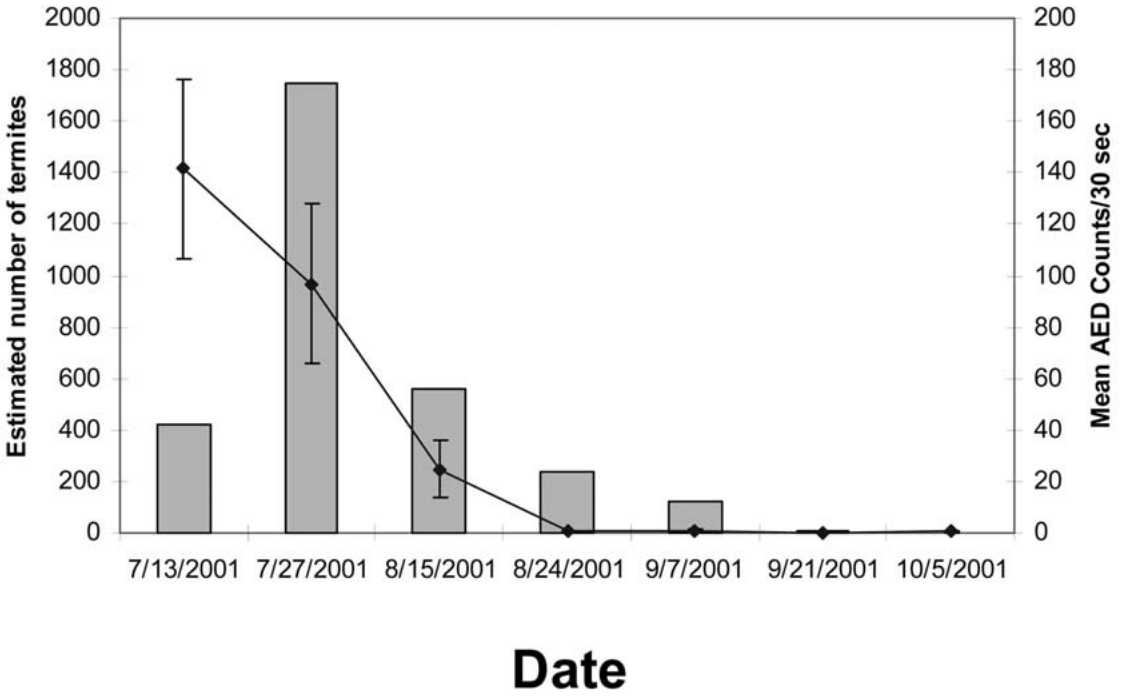

Fig. 7. Total estimated number of termites (bars) and mean (± SE) acoustic emissions counts (line) per monitoring location before, during, and after application of 0.5% noviflumuron bait, DAYCARE, Broward County, Florida, 2001.

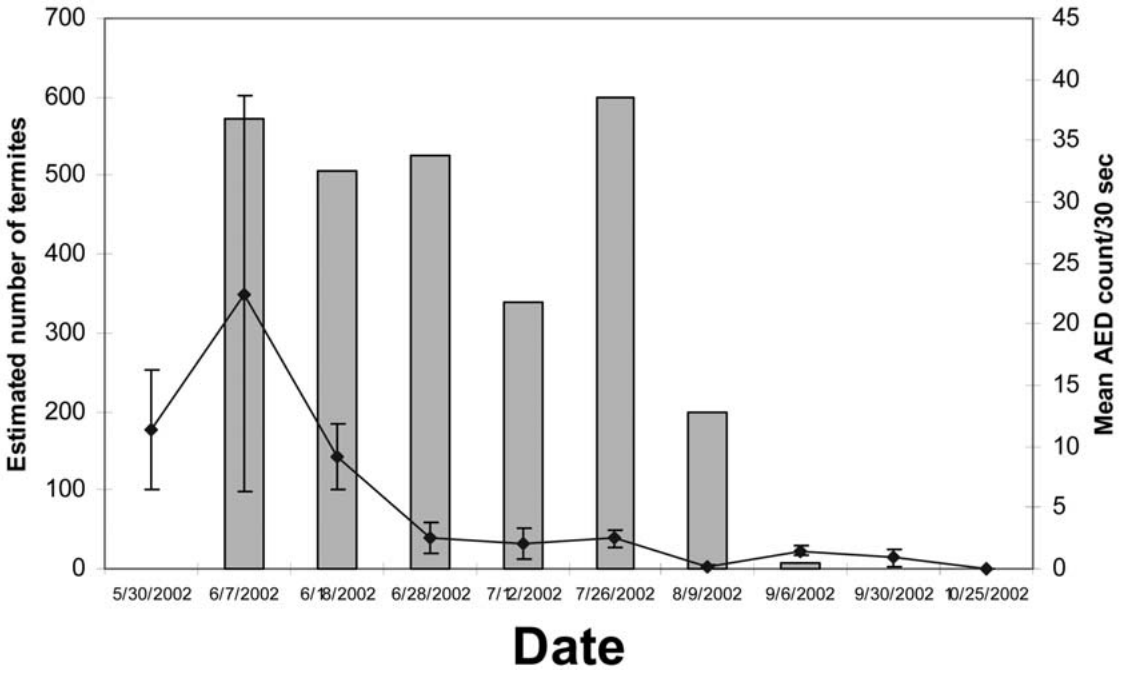

Fig. 8. Total estimated number of termites (bars) and mean (± SE) acoustic emissions counts (line) per monitoring location before, during, and after application of 0.5% noviflumuron bait, CONDO, Broward County, Florida, 2002.

flumuron baits can be applied IG and/or AG to eliminate FST populations. Unlike liquid termiticide treatments, all areas of soil access to the building for a ground-based FST population and all termite activity within the building for aboveground infestations did not need to be treated with noviflumuron baits to eliminate the structural infestation of FST. We also were able to eliminate FST infestations in two situations (CONDO and DAYCARE) where the occupants would not permit application of pesticide to indoor living or outdoor activity areas.

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FLIGHT ACTIVITY AND RELATIVE ABUNDANCE OF PHYTOPHAGOUS SCARABS (COLEOPTERA: SCARABAEOIDEA) FROM TWO LOCATIONS IN FLORIDA

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ABSTRACT

The seasonal abundance of phytophagous scarabs in Gainesville and Fort Lauderdale, Florida, was documented with ultraviolet blacklight traps operated from April 2002 to November 2004. Over 44,000 adult scarabs were trapped and identified, including 30 species from 14 genera. *Hybosorus illigeri* Reiche was the most abundant species trapped (n = 12,306 or 27.9% of total trap catches). *Phyllophaga* was the most diverse genus with ten species collected. *Tomarus cuniculus* (F.) and *Dyscinetus morator* (F.) adults were trapped every month of the year. *Anomala innuba* (F.), *Cyclocephala lurida* (Bland), *C. parallela* Casey, *H. illigeri*, and *Phyllophaga bruneri* Chapin exhibited bimodal flight patterns. Adults of these five species combined represented 49.1, 56.5, and 64.6% of the collections in 2002, 2003, and 2004, respectively. Species that occurred in both locations tended to be active earlier in Fort Lauderdale than in Gainesville. The flight activity and species composition of potential scarab pests in Florida appears to be different from those in the midwestern and northern U.S., suggesting that turfgrass and ornamental plant managers need to adjust their management strategies accordingly.

Key Words: Scarabaeoidea, flight activity, blacklight trapping

RESUMEN

La abundancia estacional de las especies fitofagas de escarabajos (Familia Scarabaeidae) en Gainesville y Fort Lauderdale, Florida, fue documentada usando trampas de luz negra ultra violeta operadas de abril 2002 hasta noviembre del 2004. Mas de 44,000 adultos fueron capturados e identificados, incluyendo 30 especies en 14 géneros. *Hybosorus illigeri* Reiche fue la especie mas abundante capturada (n = 12,306 o 27.9% del total de las especies capturadas en la trampa). *Phyllophaga* fue el género mas diverso con diez especies recolectadas. Adultos de *Tomarus cuniculus* (F.) y *Dyscinetus morator* (F.) fueron capturados en cada mes del año. *Anomala innuba* (F.), *Cyclocephala lurida* (Bland), *C. parallela* Casey, *H. illigeri* y *Phyllophaga bruneri* Chapin mostraron un patrón bimodal de vuelo. Los adultos de estas cinco especies juntas representaron 49.1, 56.5, y 64.6% de las colecciones en 2002, 2003 y 2004, respectivemente. Las especies presentes en estos dos lugares tienden a ser tempranamente mas activas en Fort Lauderdale que en Gainesville. La actividad de vuelo y la composición de especies de Scarabaeiidae que son plagas potenciales en Florida parece ser diferentes que las en la región central y norte de los Estados Unidos, esto sugiere que los de negocios de césped y de plantas ornamentales deben ajustar sus estrategias del manejo según el caso.

Through their root feeding, some immature scarab beetles (Coleoptera: Scarabaeoidea) or white grubs, are economic pests of turfgrasses, corn, sorghum, grains, vegetables, conifers, and ornamental plants (Forschler & Gardner 1990; Vittum et al. 1999). Some adult scarabs do not feed, while others partially or completely defoliate hardwood trees and shrubs (Habeck & Wolfenbarger 1968), make mounds while ovipositing in the soil, or are nuisances by being abundant and active on golf course greens and tees. In addition, birds, raccoons, moles, armadillos, and other animals can cause extensive damage when digging to find white grub prey (Potter 1998).

White grubs were considered minor pests in Florida while several chlorinated hydrocarbon and organophosphate insecticides were available for use on turfgrass (Ralph White, pers. comm.). Most of these compounds are no longer available, and white grub populations have increased and become locally damaging along the Gulf and Atlantic Coasts. Several lawn care firms have reported poor control of several scarab species that are uncommon or do not exist in other states (pers. obs.). Although lists of scarabs collected in other states and their adult phenologies have been published (see Forschler & Gardner 1991), such data are incomplete in Florida. Thus, the following blacklight study was conducted to describe the seasonality of phytophagous scarabs in Florida. This information will be used to develop an integrated pest management program for white grubs on urban turfgrasses.

Materials and Methods

The blacklight traps (BioQuip, Rancho Dominguez, CA) used in this study were AC-powered, had a 22-watt Circline bulb, and were operated day and night for the duration of the study. Traps contained an insecticidal strip (dichlorvos, Hot Shot No-Pest Strip®) to kill insects caught in the bucket. The strip was replaced monthly or as needed. A hole in the bottom and side of the bucket allowed rain water to drain. All traps were suspended ca. 2 m from the ground from a metal hook.

One trap was located at the Gainesville Golf and Country Club in Gainesville (Alachua Co.), FL. The primary turfgrass on the golf course was bermudagrass (*Cynodon dactylon* [L.] Pers.) varieties 419, Ormond, and GN1. The soil was classified as Blichton-Urban land complex (loamy, siliceous, hyperthermic Arenic Plinthic Paleaquults). The trap was operated from 4 April 2002 until 22 November 2004. Scarabs were collected once or twice a week and frozen.

The second trap was located at the Fort Lauderdale Research and Educational Center (Broward Co.), FL. It was placed near bermudagrass and St. Augustinegrass (*Stenotaphrum secundatum* [Walt.] Kuntze.) turfgrass research plots. The soil was Margate fine sand (siliceous, hyperthermic Mollic Psamnaquent). Specimens were collected once or twice a week from 30 April 2002 until 15 November 2004, and frozen.

Scarab beetles were sorted, counted, and stored in 70% ethyl alcohol (EtOH). *Hybosorus illigeri* Reiche (Coleoptera: Scarabaeoidea: Hybosoridae) was also included because the adults are nuisance pests on golf courses in Florida (pers. obs.), but the larvae may not be phytophagous (Woodruff 1973; Ocampo 2002). The genitalia of *Cyclocephala* spp. and *Phyllophaga* spp. were extracted for species and gender determination. Identifications were based on comparisons with specimens at the Florida Collection of Arthropods and keys (Gordon & Anderson 1981; Woodruff & Beck 1989; Arnett et al. 2002). Identifications were confirmed by M. Thomas and P. Skelley, and voucher specimens were deposited at the Florida Collection of Arthropods at the Division of Plant Industry, Gainesville, FL.

Results and Discussion

During this study, >44,000 adult scarabs were trapped and identified, including 30 species from 14 genera. The total number of scarabs caught in traps (Tables 1 and 2) varied somewhat each year at both sites (11,334 beetles in 2002, 16,916 beetles in 2003, and 15,791 beetles in 2004). The number of species and genera also varied over time (22 species and ten genera in 2002, 28 species and 14 genera in 2003, and 26 species and 12 genera in 2004). The trapped scarabs were more diverse at the Gainesville site (25 species) than at the Fort Lauderdale site (14 species). However, species that occurred in both locations tended to be active earlier in Fort Lauderdale than in Gainesville. The most abundant species captured in the light traps in 2002 was *Dyscinetus morator* (F.) (n = 4,550), but *H. illigeri* was the predominant species collected in 2003 (n = 4,942) and 2004 (n = 5,155). The species composition of phytophagous scarabs in Florida had some slight overlap with other southeastern states (Forschler & Gardner 1991; Flanders et al. 2000; Harpootlian 2001).

Three species of *Anomala*, *A. innuba* (F.), *A. marginata* (F.), and *A. undulata* Melsheimer, were collected, which represented 13.5% of the total catch during this study (n = 5,964). This was the most abundant genus in 2003 and 2004. *Anomala innuba* exhibited bimodal flight activity at both locations (Fig. 1), with peak activity from late April to mid-May and early August to mid-September in Gainesville and from early April to mid-May and late August to mid-October in Fort Lauderdale. It had one flight peak in Alabama and Kansas (Hayes 1925; Flanders et al. 2000). The number of *A. innuba* collected in the Fort Lauderdale trap appeared to be increasing each year, which might indicate a growing pest problem there. Although not detected in this study, Hall (1987) observed a bimodal flight pattern of *A. marginata* in a sugarcane field in south-central Florida. This species has a unimodal flight pattern in Kentucky and North Carolina (Brimley 1938; Ritcher 1966). *Anomala* spp. larvae attack grass roots (Hayes 1925).

Cyclocephala spp. represented 13.0% of the total catch (n = 5,720). Several *Cyclocephala* spp. have been considered among of the most damaging white grub pests of sugarcane and turfgrass in Florida (Reinert 1979; Hall 1987). The southern masked chafer *C. lurida* (Bland.) had two flight peaks each year in Gainesville (Fig. 2), which has not been previously documented, and the species was not collected in Fort Lauderdale. In other unpublished research, third instars were collected in July, pupation occurred in late July and early August, and the adults were identified (pers. obs.). Its peak adult activity occurred from early May to mid-June for the first generation and early August to late September for the second generation. Peak flight periods for *C. lurida* typically occur in June and July in other states (Flanders et al. 2000). *Cyclocephala parallela* Casey had one flight peak in Gainesville but had a bimodal flight pattern in Fort Lauderdale (Fig. 3). Peak adult activity for *C. parallela* was in early June in Gainesville, and from late April to early June and mid-August to late September in Fort Lauderdale. However, in a study conducted in a south-central Florida sugarcane field, peak *C. parallela* adult

TABLE 1. PHYTOPHAGOUS SCARAB BEETLES COLLECTED WITH BLACKLIGHT TRAPS IN GAINESVILLE, FL, FROM 2002 TO 2004.

Species	Year	*n*	Flight period	Peak activity
Anomala innuba (F.)	2002	168	Apr. 12-Sep. 26	Apr. 25-May 9 Aug. 1-8
	2003	68	Apr. 21-Oct. 6	May 5-12 Aug. 21-Sep. 11
	2004	73	Apr. 29-Sep. 21	May 10-17 Aug. 13-30
Anomala marginata (F.)	2002	33	May 2-July 18	June 3-17
	2003	58	Apr. 10-July 17	June 2-19
	2004	143	May 20-Aug. 19	June 10-28
Anomala undulata Melsheimer	2002	88	Apr. 8-May 2	Apr. 12-May 2
	2003	178	Feb. 25-June 9	Mar. 3-Apr. 8
	2004	22	Mar. 1-May 17	Mar. 8-Apr. 12
Aphonus variolosus (LeConte)	2003	1	June 9	—
Cyclocephala lurida (Bland.)	2002	1,579	Apr. 12-Dec. 5	May 2-June 17 Aug. 8-Sep. 26
	2003	955	Apr. 24-Nov. 17	May 5-June 16 Aug. 14-Sep. 29
	2004	1,075	Apr. 26-Nov. 1	May 20-June 21
Cyclocephala parallela Casey	2002	39	May 20-July 15	May 30-June 17
	2003	20	May 22-June 26	May 27-June 9
	2004	16	June 10-July 12	June 14-21
Cyclocephala seditiosa LeConte	2003	1	June 5	—
Diplotaxis punctatorugosa Blanchard	2002	8	Apr. 15-June 6	—
	2003	5	May 29-Aug. 14	—
	2004	1	Apr. 26	—
Dyscinetus morator (F.)	2002	4,217	Apr. 8-Nov. 14	Apr. 12-May 20
	2003	3,386	Feb. 10-Dec. 8	Feb. 25-Apr. 8
	2004	1,761	Jan. 5-Nov. 22	Mar. 8-Apr. 12
Euetheola humilis rugiceps (LeConte)	2002	50	Apr. 8-Nov. 7	Apr. 18-May 4
	2003	96	Mar. 13-Nov. 13	Mar. 17-Apr. 8
	2004	39	Mar. 8-Oct. 4	Mar. 29-Apr.19
Hybosorus illigeri Reiche	2002	587	Apr. 25-Oct. 7	May 2-June 17 Sep. 2-13
	2003	292	Apr. 8-Oct. 30	May 19-June 9 Aug. 14-Sep. 8
	2004	533	May 3-Oct. 22	May 24-June 28 Sep. 13-21
Pelidnota punctata (L.)	2002	29	May 2-July 8	May 20-30
	2003	34	May 8-Aug. 14	June 2-9
	2004	72	May 10-Aug. 30	June 7-24
Phyllophaga crenulata (Froelich)	2002	3	Apr. 8-May 9	—
	2003	5	Mar. 20-June 9	—
	2004	10	Mar. 15-May 6	—
Phyllophaga debilis (LeConte)	2002	1	May 30	—
	2004	1	May 24	—
Phyllophaga glaberrima (Blanchard)	2002	39	May 9-Aug. 26	June 6-17
	2003	63	June 2-Aug. 25	June 9-30
	2004	66	May 24-Aug. 26	June 14-24

TABLE 1. (CONTINUED) PHYTOPHAGOUS SCARAB BEETLES COLLECTED WITH BLACKLIGHT TRAPS IN GAINESVILLE, FL, FROM 2002 TO 2004.

Species	Year	*n*	Flight period	Peak activity
Phyllophaga latifrons (LeConte)	2002	109	May 2-July 11	May 30-June 17
	2003	75	May 12-Aug. 14	June 2-12
	2004	28	May 27-Aug. 2	June 14-July 6
Phyllophaga parvidens (LeConte)	2004	1	May 3	—
Phyllophaga prununculina (Burmeister)	2002	25	May 16-July 4	—
	2003	32	June 2-July 14	—
	2004	30	June 14-Aug. 2	—
Phyllophaga quercus (Knoch)	2002	121	May 30-Aug. 1	June 6-July 4
	2003	115	May 27-Aug. 21	June 19-July 7
	2004	204	June 7-Aug. 13	June 14-July 12
Phyllophaga tecta Cartwright	2003	22	Mar. 20-June 9	—
	2004	9	Mar. 29-June 14	—
Phyllophaga uniformis (Blanchard)	2002	393	May 2-July 11	May 30-June 17
	2003	568	May 8-Aug. 14	May 27-June 30
	2004	852	May 10-July 29	June 7-28
Polyphylla occidendentalis (L.)	2002	3	Apr. 15-May 2	—
	2003	5	Apr. 28-May 22	—
	2004	2	May 10-June 17	—
Serica sericea (Illiger)	2003	3	Mar. 20-Apr. 10	—
Strategus antaeus (Drury)	2003	2	Aug. 14-Sep. 2	—
	2004	1	June 28	—
Tomarus gibbosus DeGeer	2002	8	Apr. 25-May 20	—
	2003	27	Apr. 21-Sep. 18	—
	2004	21	Apr. 29-Sep. 28	—

activity only occurred from mid-April to mid-May (Hall 1987). Trap catches contained primarily male *C. lurida* (91.7%) and *C. parallela* (90.4%), but only 43.5% of *C. miamiensis* (Howden and Endrodi) were male. Just one male *C. seditiosa* LeConte was collected in this study.

The rice beetle, *Dyscinetus morator* (F.), was abundantly collected (*n* = 9,493 or 21.6% of the total catch) nearly every month of the year, with peak flight occurring between February and May in Gainesville. Its peak flight period occurred in May and June in Alabama and Georgia (Flanders et al. 2000), but a second generation may occur in August and September in Georgia (Forschler & Gardner 1991). Woodruff (1970) also suggested that *D. morator* was bivoltine in southern Florida, based on the occurrence of greater adult activity in the spring and fall and Smyth's (1915) data indicating that other *Dyscinetus* spp. could go from egg to adult in ≤144 days in Puerto Rico. However, only one peak of adult activity was detected each of the three years of this Florida study. It is known to inhabit wet soils, marsh areas (Buckingham & Bennet 1989), and compost (Ritcher 1966). Larvae feed on rice, pangola grass pastures, crabgrass, water hyacinth, caladium bulbs, and azaleas (Staines 1990).

Phyllophaga spp. represented 12.8% of the total catch during this study (*n* = 5,643). Fifty-four species of *Phyllophaga* occur in Florida (Woodruff & Beck 1989), but only nine species were collected in Gainesville, compared to the three species collected in Fort Lauderdale. Only *P. glaberrima* (Blanchard) and *P. latifrons* (LeConte) occurred at both sites in this study, and are known to have a statewide distribution (Woodruff & Beck 1989). The most abundant species was *P. bruneri* Chapin (*n* = 2,240), which was only collected in Fort Lauderdale (Fig. 4) and is unique within this genus by exhibiting a bimodal flight pattern (Fig. 4), representing two distinct generations, and is active every month of the year in southern Florida (Habeck & Wolfenbarger 1968). The earliest flight activity in the year consistently began with *P. crenulata* (Froelich) and *P. tecta* Cartwright in March in Gainesville and *P. glaberrima* and *P. latifrons* in Fort Lauderdale. Species that were active from May to August included *P. glaberrima*, *P. latifrons*, and *P. quercus* (Knoch), which have similar flights in Alabama (Flanders et al. 2000)

TABLE 2. PHYTOPHAGOUS SCARAB BEETLES COLLECTED WITH A BLACKLIGHT TRAP IN FT. LAUDERDALE, FL, FROM 2002 TO 2004.

Species	Year	*n*	Flight period	Peak activity
Anomala innuba (F.)	2002	493	Apr. 30-Dec. 31	Apr. 30-May 14 Sep. 3-Oct. 8
	2003	1,952	Jan. 3-Dec. 26	Apr. 1-May 8 Aug. 26-Oct. 21
	2004	2,468	Jan. 6-Nov. 11	Apr. 9-May 4 Aug. 31-Oct. 16
Anomala marginata (F.)	2002	69	Apr. 30-Dec. 31	—
	2003	80	Jan. 3-Dec. 26	—
	2004	71	Jan. 6-Nov. 15	—
Cyclocephala miamiensis (Howden & Endrodi)	2002	4	Apr. 30-May 10	—
	2003	133	Apr. 22-May 16	—
	2004	35	Apr. 27-June 15	—
Cyclocephala parallela Casey	2002	312	Apr. 30-Dec. 13	May 10-28 Aug. 13-Sep. 28
	2003	1,004	Mar. 14-Nov. 21	Apr. 4-May 20 Aug. 19-Sep. 30
	2004	547	Feb. 24-Oct. 25	May 4-June 12 Aug. 31-Oct. 1
Dyscinetus morator (F.)	2002	33	Aug. 6-Dec. 27	—
	2003	59	Feb. 4-Dec. 30	—
	2004	37	Jan. 9-Oct. 18	—
Euphoria sepulcralis (F.)	2003	10	Feb. 28-July 8	—
	2004	22	Feb. 17-Aug. 10	—
Euetheola humilis rugiceps (LeConte)	2004	1	Jan. 20	—
Hybosorus illigeri Reiche	2002	1,622	Apr. 30-Dec. 27	May 6-June 6 Aug. 6-Sep. 17
	2003	4,650	Feb. 11-Dec. 5	May 6-June 3 July 22-Sep. 5
	2004	4,622	Apr. 27-Nov. 4	May 25-June 29 Aug. 10-Sep. 17
Pelidnota punctata (L.)	2002	2	Apr. 30-May 10	—
	2003	38	Apr. 1-May 13	—
	2004	16	Mar. 23-July 9	—
Phyllophaga bruneri Chapin	2002	760	Apr. 30-Dec. 24	Apr. 30-May 28 July 26-Aug. 20
	2003	617	Feb. 25-Dec. 26	Apr. 22-May 13 Aug. 19-Sep. 23
	2004	863	Jan. 2-Oct. 21	Apr. 23-June 1 Aug. 17-Sep. 17
Phyllophaga glaberrima (Blanchard)	2002	4	May 10-Dec. 10	—
	2003	66	Mar. 25-Sep. 2	—
	2004	68	Mar. 19-Aug. 24	—
Phyllophaga latifrons (LeConte)	2002	31	Apr. 30-July 18	—
	2003	222	Mar. 21-July 18	Apr. 29-May 13
	2004	240	Mar. 23-Aug. 24	May 25-June 12
Tomarus cuniculus (F.)	2002	501	Apr. 30-Dec. 31	—
	2003	2,076	Jan. 3-Dec. 30	—
	2004	1,841	Jan. 28-Nov. 18	—
Tomarus subtropicus (Blatchley)	2003	1	July 1	—

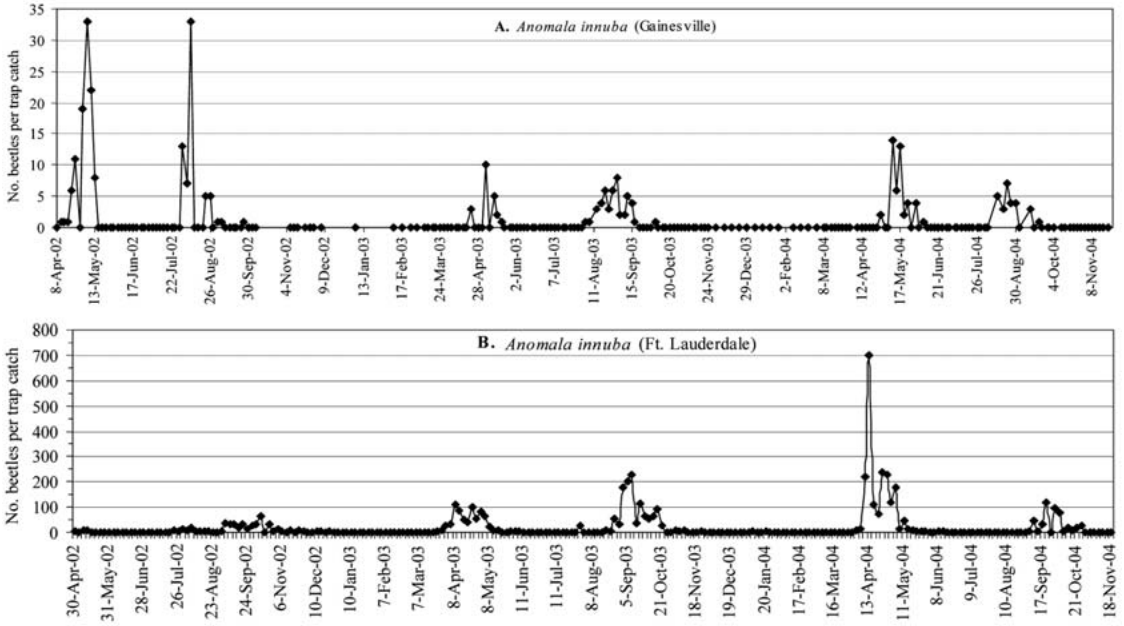

Fig. 1. Flight activity of *A. innuba* at blacklight traps located in Gainesville (A) and Fort Lauderdale, FL (B).

and are probably univoltine (Luginbill & Painter 1953; Flanders et al. 2000). Genders for all adult *Phyllophaga* spp. trapped from 2002 to 2004 were identified. Species that had more males than females collected in traps, averaged over the three years, included *P. crenulata* (93.3% male), *P. glaberrima* (94.1%), *P. latifrons* (64.4%), *P. parvidens* (LeConte) (100%), *P. prununculina* (Burmeister) (92.3%), *P. quercus* (91.6%), *P. tecta* (85.4%), and *P. uniformis* (Blanchard) (59.5%). Only *P. bruneri* (47.0% male) and *P. debilis* (LeConte) (50%) had more of a female bias. Nearly all of these species can damage ornamental plant foliage as adults, and many of the larvae infest nursery stock or turfgrass (Woodruff & Beck 1989).

Tomarus spp. (formerly *Bothynus* and *Ligyrus*) represented 10.2% of the total catch (n = 4,475). The carrot beetle, *T. gibbosus* (DeGeer), which is a pest of various vegetable crops (Hayes 1917), was collected only in Gainesville. *Tomarus cuniculus* (F.), only collected in Fort Lauderdale, is an invasive species that can cause significant turfgrass damage along the Atlantic Coast of Florida. Adults were abundantly collected in the Fort Lauderdale trap nearly every month of the year without a distinct peak period of activity. Only one

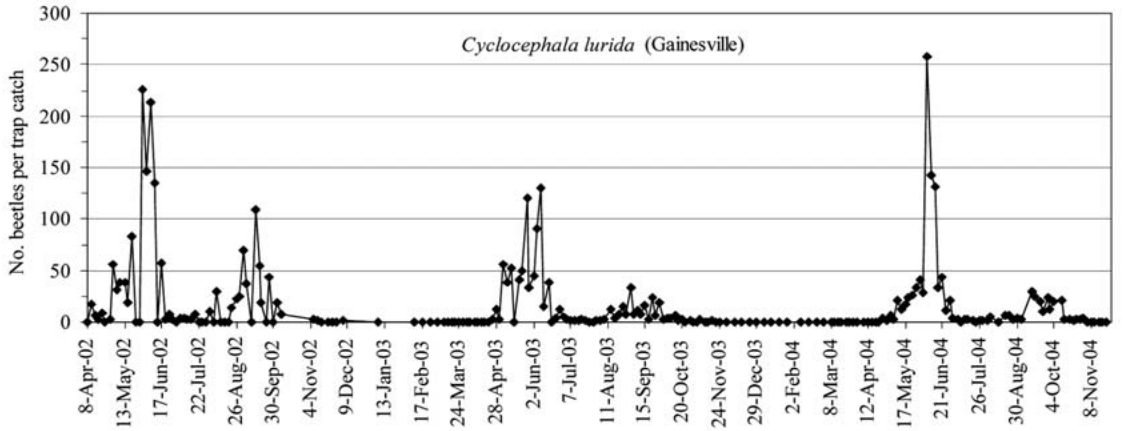

Fig. 2. Flight activity of the southern masked chafer, *C. lurida*, in Gainesville, FL.

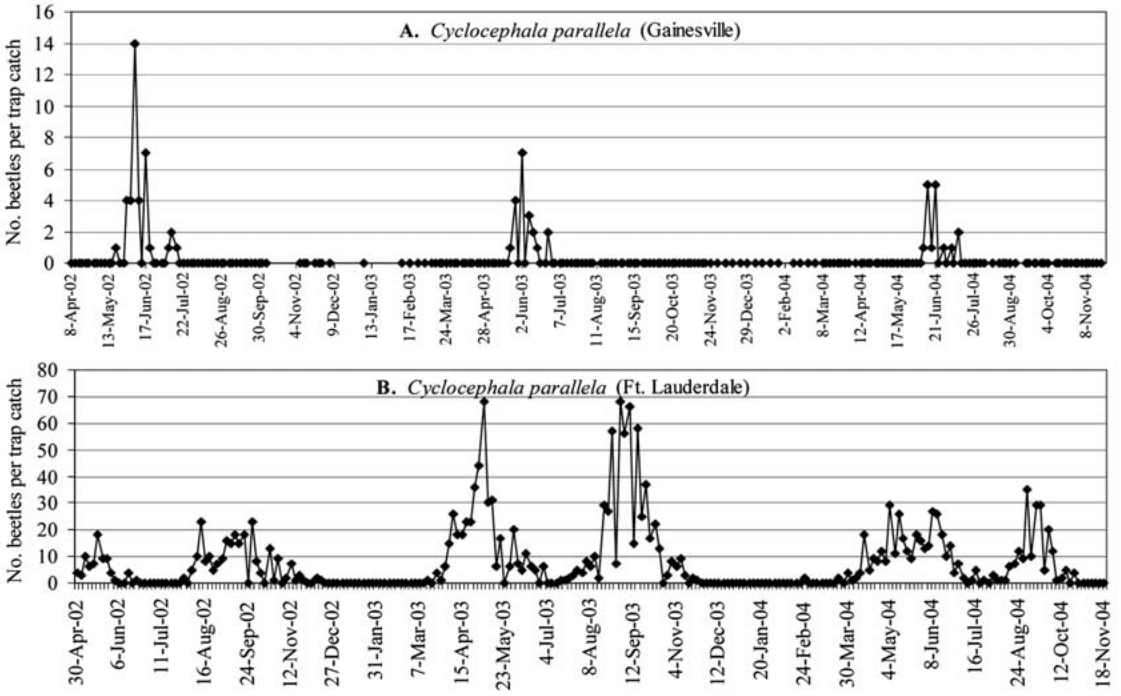

Fig. 3. Flight activity of *C. parallela* at blacklight traps located in Gainesville (A) and Fort Lauderdale, FL (B).

T. subtropicus (Blatchley) flew to a black light trap. This species tends to be more abundant along the Gulf Coast in St. Augustinegrass (pers. obs.) and is considered a primary pest of sugarcane (Gordon & Anderson 1981). Adult *T. subtropicus* are active from April to July in sugarcane in south-central Florida (Cherry 1985).

Hybosorus illigeri was collected at the light traps from April to October in Gainesville and nearly all year in Fort Lauderdale (n = 12,306 beetles from both sites, or 27.9% of the total catch). Although Woodruff (1973) considered *H. illigeri* to be univoltine, two peaks of activity (May to June, August to September) were consistently observed in this study at both locations (Fig. 5). The smaller second flight peak suggests that not all individuals fully complete a second generation. Little is known about its biology (Woodruff 1973; Ocampo 2002), but it has been collected at light, in dung, in carrion, and has been observed feeding on other scarabs (see Ocampo 2002). The abundance of adults and the small mounds that they make on golf course tees and greens are annoying to golfers and golf course superintendents,

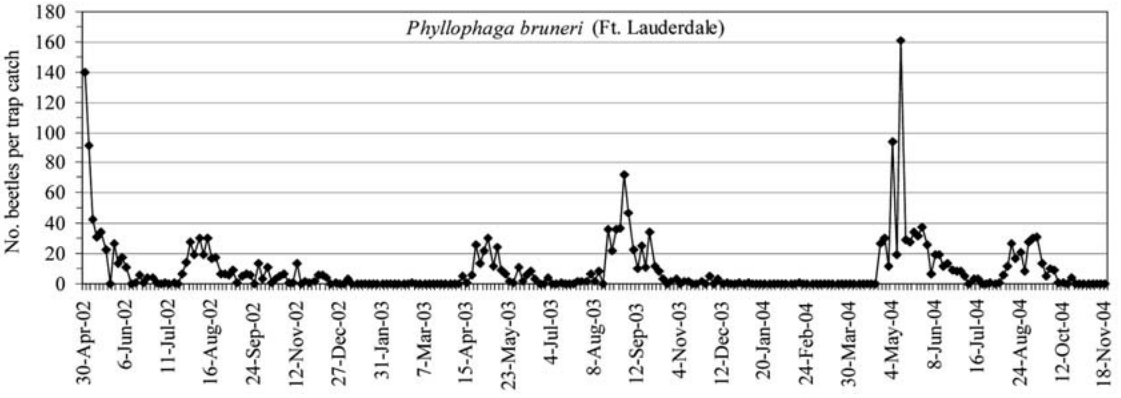

Fig. 4. Flight activity of the Cuban May beetle, *P. bruneri*, in Fort Lauderdale, FL.

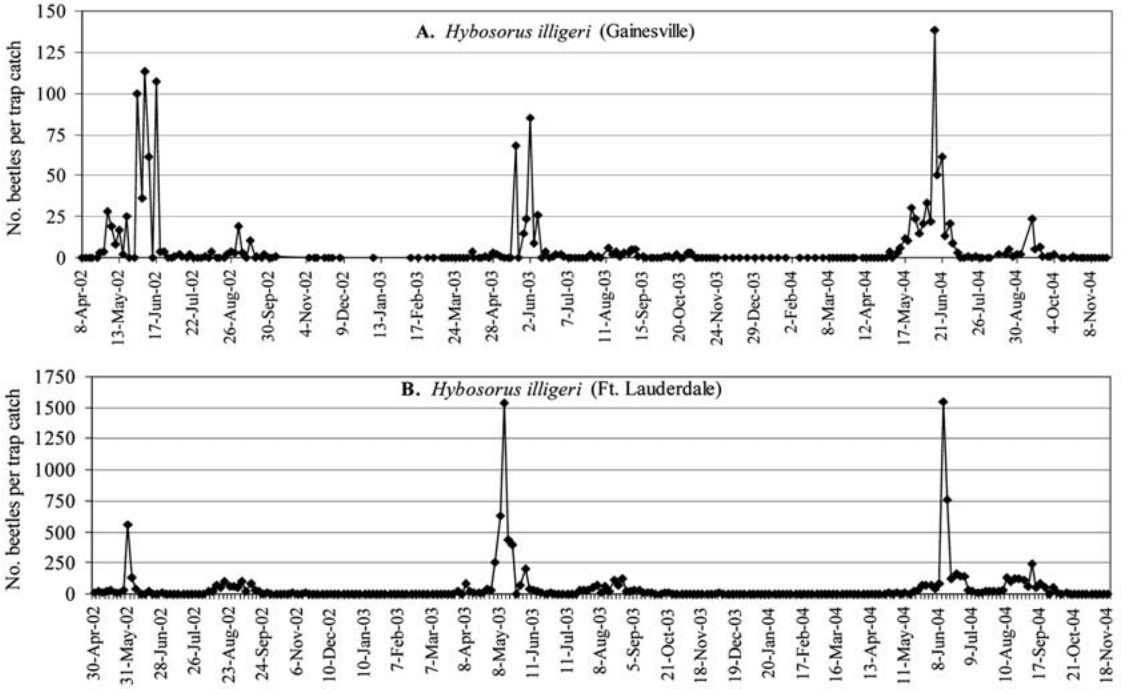

Fig. 5. Flight activity of *H. illigeri* at blacklight traps located in Gainesville (A) and Fort Lauderdale, FL (B).

but turf damage is not apparent even where densities are high (pers. obs.).

The existence of a bimodal flight pattern for several scarab species in Florida could be the result of several factors, which might be resolved by collecting adults and rearing the subsequent generation(s) under controlled conditions. It is possible that two similar species or an undescribed invasive species might coincide in an area, but adults may not have been taxonomically separated. Especially with individuals beginning their flights early in the year, egg and/or larval development might be at least initially slower due to cooler and drier conditions (Gaylor & Frankie 1979; Potter 1981) than those individuals that fly and lay eggs during the warmer and more humid Florida summer. However, because some individuals are simply active earlier, one generation may have time to complete development and allow at least a partial second generation to occur later in the year. Turfgrass is an available and consistent food source for grubs throughout the year in southern Florida, but warm season grasses decline in the fall and transition back in the spring in northern Florida. Insect development time also may be affected by changes in fertilization and watering practices in winter months compared to summer months. In addition, individuals or populations could diapause during adverse conditions. A second flight peak of several scarab species may not have been detected in studies specifically done on sugarcane fields if flooding during the summer or early fall was done to control grub populations (Cherry 1984), if cane height reduced black light visibility, or if the crop had been harvested.

More information is needed on the biology, damage potential, and management of these key scarabs. White grub populations are increasing in importance in Florida turfgrass production and maintenance industries. Older, broad-spectrum insecticides, which may have kept white grub numbers below damaging levels, have been replaced with products which lack efficacy against root-feeding scarabs (e.g., pyrethroids, fipronil). Management strategies based on application timing determined in more northern states have not provided satisfactory results in Florida. According to the data in this study, most scarab adults are active from April to June, which may be the most appropriate timing for preventive insecticide applications against young white grubs, if needed.

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STATUS AND DISTRIBUTION OF *MONTANDONIOLA MORAGUESI* (HEMIPTERA: ANTHOCORIDAE) IN THE CONTINENTAL UNITED STATES

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ABSTRACT

The exotic anthocorid *Montandoniola moraguesi* (Puton) was intentionally introduced in Hawaii and Bermuda for the control of thrips on outdoor plantings of ornamental *Ficus*. These successful programs resulted in similar efforts to introduce this predator at several locations within the continental United States. Such attempts to establish the bug as a component of biological control systems aimed at pest thrips apparently have been unsuccessful. Our surveys and requests for museum records revealed detections of *M. moraguesi* in four states: Alabama, Florida, Louisiana, and Mississippi. Circumstances surrounding detections in Alabama, Louisiana, and Mississippi suggest that viable populations may not currently exist in those states. *M. moraguesi* occurs widely throughout peninsular Florida, wherever outdoor plantings of exotic, ornamental *Ficus* spp. are found. An updated distribution of *M. moraguesi* is provided along with field observations and new thrips host records.

Key Words: biological control, predator, thrips, Thysanoptera, Florida

RESUMEN

El antocórido exótico *Montandoniola moraguesi* (Puton) fue introducido intencionalmente en Hawaii y Bermuda para el control de trips en las siembras de campo de plantas ornamentales del género *Ficus*. Estos programas con exito resultaron en esfuerzos similares para introducir este depredador en varios lugares en el continente de los Estados Unidos. Los intentos para establecer este chinche como un componente de un sistema de control biológico dirigido a las plagas de trips aparentemente no se han logrado. Nuestras busquedas y pedidos de registros de museo revelaron que *M. moraguesi* fue detectado en cuatro estados: Alabama, Florida, Louisiana, y Mississippi. Las circumstancias alrededor de las detecciones en Alabama, Louisiana, y Mississippi sugieren que poblaciones viables tal vez ya no existen en estos estados. *Montandoniola moraguesi* esta ampliamente distribuida por la peninsula del Florida, donde se encuentra siembras de campo de plantas ornamentales exóticas de *Ficus* spp. Se provee una distribución mas actualizada de *M. moraguesi* adjunto con las observaciones de campo y nuevos registros de los hospederos de trips.

Montandoniola moraguesi (Puton) (Hemiptera: Anthocoridae) (Fig. 1) is an important predator of several species of economically important thrips. Although originally described in France, *M. moraguesi* now is thought to be native to Southeast Asia (Herring 1967; Lattin 2000). Its reported distribution is essentially Old World. Populations are known from Africa (Algeria, Egypt, Morocco, Senegal, South Africa, Sudan, Western Sahara), Asia (Japan, Israel, Philippines, Micronesia), Australia, Europe (Canary Islands, France, Italy, Portugal, Sicily, Spain) and Bermuda (Carayon & Ramade 1962; Funasaki 1966; Herring 1967; Lewis 1973; Muraleedharan 1977; Muraleedharan & Ananthakrishnan 1978; Péricart & Halperin 1989; Postle et al. 2001). In the Western Hemisphere, it has been reported only from South America (Muraleedharan & Ananthakrishnan 1978), although it may exist throughout much of the Caribbean and Latin America. Its prey includes more than 20 species of gall-forming thrips (Table 1) from a wide variety of host plants (Muraleedharan & Ananthakrishnan 1978).

Because of its broad host range, *M. moraguesi* sometimes is a useful biological control agent against thrips. It has been successfully introduced for the biological control of *Gynaikothrips ficorum* (Marchal) (Thysanoptera: Phlaeothripidae) in Bermuda (Leighton 1978) and Hawaii (Funasaki 1966). In both areas, the bug became established and provided good, long-term control, but its establishment in Hawaii has caused biotic interference (Reimer 1988). In the continental United States, however, two attempted introductions in California (1965 and 1996) and at least one in Texas (1992) apparently have not been successful (Clausen 1978; Henry 1988; Paine 1992; Hanlon & Paine 2003).

Fig. 1. *Montandoniola moraguesi*, dorsal view.

The primary pest target of *M. moraguesi* in the United States has been the Cuban laurel thrips, *G. ficorum*. Feeding by this thrips, a pest of Chinese banyan *Ficus microcarpa* L. (Moraceae) (Paine 1992), causes the leaves to fold upward into galls where the thrips breeds and forms large colonies. Recently, a second species *G. uzeli* Zimmerman has become established in the United States (Held et al. 2005). *Gynaikothrips uzeli*, a pest of weeping fig, *F. benjamina* (L.), was accidentally introduced into Florida and is now being spread throughout the southeastern United States in shipments of ornamental weeping fig originating from nurseries in South Florida (Held et al. in press). The primary morphological difference between these thrips is the relative lengths of the pronotal posterolateral pair of setae, but a more practical way to distinguish *G. ficorum* from *G. uzeli* is by host-plant association: *G. ficorum* with *F. microcarpa* and *G. uzeli* with *F. benjamina* (Mound et al. 1995). *Ficus microcarpa* survive in plant zones 9-11, whereas *F. benjamina* survive in zones 10-11 (Turner & Wasson 1997).

The Cuban laurel thrips occurs in California, Florida, and Texas (Denmark 1967) in the continental United States. Even though the thrips has been known from Florida since at least 1887 (Denmark 1967), *M. moraguesi* was not detected in that state until 1990. The discovery of this anthocorid in Florida was based on adults and nymphs collected from curled and deformed *Ficus* leaves in Palm Beach County (Bennett 1995). No records of intentional introductions of *M. moraguesi* in Florida are available and its presence there might be due to unintentional spread through commerce or through natural means.

Although *M. moraguesi* has been detected in Palm Beach County, Florida, exact locality data have not been reported. Herein we confirm the establishment of *M. moraguesi* in South Florida 15 years after its initial detection, provide updated information on distribution, report records from museum searches in several states where the bug potentially could become established outdoors, summarize our field observations, and provide new prey records.

Materials and Methods

In the continental United States, plant zones 9-11, i.e., those areas capable of supporting outdoor populations of ornamental *Ficus* spp., encompass peninsular Florida, coastal Louisiana, southern areas of Texas and Arizona, and coastal California. Based on the premise that the distribution of *M. moraguesi* coincides with that of its prey (Bennett 1995), we surveyed these areas and/or requested specimen data from major entomological museums.

We conducted surveys in Alabama, Arizona, Florida, Louisiana, Mississippi, and Texas. Various techniques were employed, including visual inspection and shaking of leaves and stems of ornamental *Ficus* spp. over a collecting net. Adults were aspirated, preserved in alcohol, and transported to the laboratory for curation and identification.

Museum records were solicited from Alabama (Auburn University Entomology Museum, Auburn), Arizona (Arizona Department of Agriculture, Phoenix; University of Arizona, Tucson), California (California Academy of Sciences, San Francisco; California Department of Agriculture, Sacramento; San Diego Natural History Museum, San Diego; University of California, Berkeley; University of California, Davis; University of California, Riverside), Florida (Florida State Collection of Arthropods, Gainesville), Louisiana (Louisiana State University, Baton Rouge), Mississippi (Mississippi State University, Starkville), Texas (Texas A & M University, College Station), and

TABLE 1. THRIPS TAKEN AS PREY BY *MONTANDONIOLA MORAGUESI* AND THEIR ASSOCIATED HOST PLANTS.

Thrips prey	Host plant	Reference
Alcothrips hadrocerus (Karny)	*Gymnosporia* sp.	Muraleedharan & Ananthakrishnan 1978
Androthrips flavipes Schmutz	Unknown	Muraleedharan & Ananthakrishnan 1978
Androthrips ramachandrai Karny	*Ficus microcarpa*	FSCA[1] E2002-1796
Aneurothrips punctipennis Karny	*Cordia* sp.	Muraleedharan & Ananthakrishnan 1978
Arrhenothrips dhumrapaksha Ramak.	*Ficus bengalensis*	Muraleedharan & Ananthakrishnan 1978
Arrhenothrips ramakrishnae Hood	*Mimusops elengi*	Muraleedharan & Ananthakrishnan 1978
Austrothrips cochinchinensis Karny	*Calycopterus floribundus*	Muraleedharan & Ananthakrishnan 1978
Brachythrips dantahasta Ramak.	*Memecylon* sp.	Muraleedharan & Ananthakrishnan 1971
Cercothrips nigrodentatus (Karny)	*Planchona valida*	Muraleedharan & Ananthakrishnan 1978
Crotonothrips gallarum Anan.	*Memecylon* sp.	Muraleedharan & Ananthakrishnan 1978
Frankliniella occidentalis (Pergande)	Unknown	Sabelis & Van Rijn 1997
Gynaikothrips bengalensis Anan.	*Ficus benjamina*	Muraleedharan & Ananthakrishnan 1978
Gynaikothrips ficorum (Marchal)	*Ficus microcarpa*	Mound et al. 1995
Gynaikothrips flaviantennatus Moulton	*Cassearia tomentosa*	Muraleedharan & Ananthakrishnan 1978
Gynaikothrips malabaricus Ramak.	*Ficus bengalensis*	Muraleedharan & Ananthakrishnan 1978
Gynaikothrips uzeli Zimm.	*Ficus benjamina*	Mound et al. 1995
Holopothrips sp.	*Tabebuia pallida*	FSCA[1] E2002-5207
Liothrips ramakrishnae Anan. & Jag.	*Schefflera racemosa*	Muraleedharan & Ananthakrishnan 1978
Liothrips africanus Vuil.	*Guierra senegalensis*	Carayon & Ramade 1962
Liothrips citricornis Anan.	*Maytenus sengalensis*	Muraleedharan & Ananthakrishnan 1971
Liothrips fluggeae Bourn.	*Gluggea virosa*	Carayon & Ramade 1962
Liothrips indicus Anan.	*Maytenus senegalensis*	Muraleedharan & Ananthakrishnan 1978
Liothrips oleae Costa	*Olea europea*	Carayon & Ramade 1962
Liothrips pallicrus (Karny)	*Vitis* sp.	Muraleedharan & Ananthakrishnan 1978
Liothrips pallipes (Karny)	*Peperomia* sp.	Muraleedharan & Ananthakrishnan 1978
Liothrips urichi Karny	*Clidemia hirta*	Reimer 1988
Lygothrips jambuvasi (Anan.)	*Terminalia* sp.	Muraleedharan & Ananthakrishnan 1978
Mesothrips extensivus Anan. & Jag.	*Mallotus phillipinus*	Muraleedharan & Ananthakrishnan 1978
Mesothrips jordani Zimm.	*Ficus benjamina*	Muraleedharan & Ananthakrishnan 1978
Nesothrips sp.	*Ficus aurea*	FSCA[1] E2001-2090
Phorinothrips loranthi Anan.	*Loranthus* sp.	Muraleedharan & Ananthakrishnan 1978
Psenothrips priesneri (Anan.)	*Walsura piscidea*	Muraleedharan & Ananthakrishnan 1978
Schedothrips orientalis Anan.	*Ventilago maderaspatana*	Varadarasan and Ananthakrishnan 1981
Tetradothrips foliiperda (Karny)	*Pothos scandans*	Muraleedharan & Ananthakrishnan 1978
Teuchothrips longus Priesner	*Pavetta hispidula*	Varadarasan and Ananthakrishnan 1981
Thrips sp.	*Ficus craterostoma*	Carayon & Ramade 1962
Thrips tabaci (Lindeman)	Unknown	Sabelis & Van Rijn 1997
Trichothrips houardi Vuil.	*Guierra senegalensis*	Carayon & Ramade 1962

[1]Florida State Coll. of Arthropods, Florida Dept. Agr. and Cons. Serv, Div. of Plant Ind.

the District of Columbia (National Museum of Natural History, Smithsonian Institution, Washington, D.C.). We also solicited data from the collections of John D. Lattin (retired) (Oregon State University, Corvallis, OR) and Tamera Lewis (USDA, ARS, Wapato, WA), both of whom have collected anthocorids from southern California.

Acronyms used are FSCA (Florida State Collection of Arthropods, Gainesville, FL), LSU (Louisiana State University Entomology Museum, Baton Rouge, LA), MIS (United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Miami Inspection Station, Miami, FL), NMNH (United States National Museum of Natural History, Washington, D.C.), and SHL (United States Department of Agriculture, Agricultural Research Service, Southern Horticultural Laboratory, Poplarville, MS).

RESULTS AND DISCUSSION

Based on field searches and museum records, specimens of *M. moraguesi* are reported from Alabama, Florida, Louisiana, and Mississippi (Fig. 2). In Alabama and Mississippi, it was taken only in retail garden centers, therefore, field populations might not occur in those states. Little is known concerning the circumstances surrounding the single specimen housed at LSU. If popula-

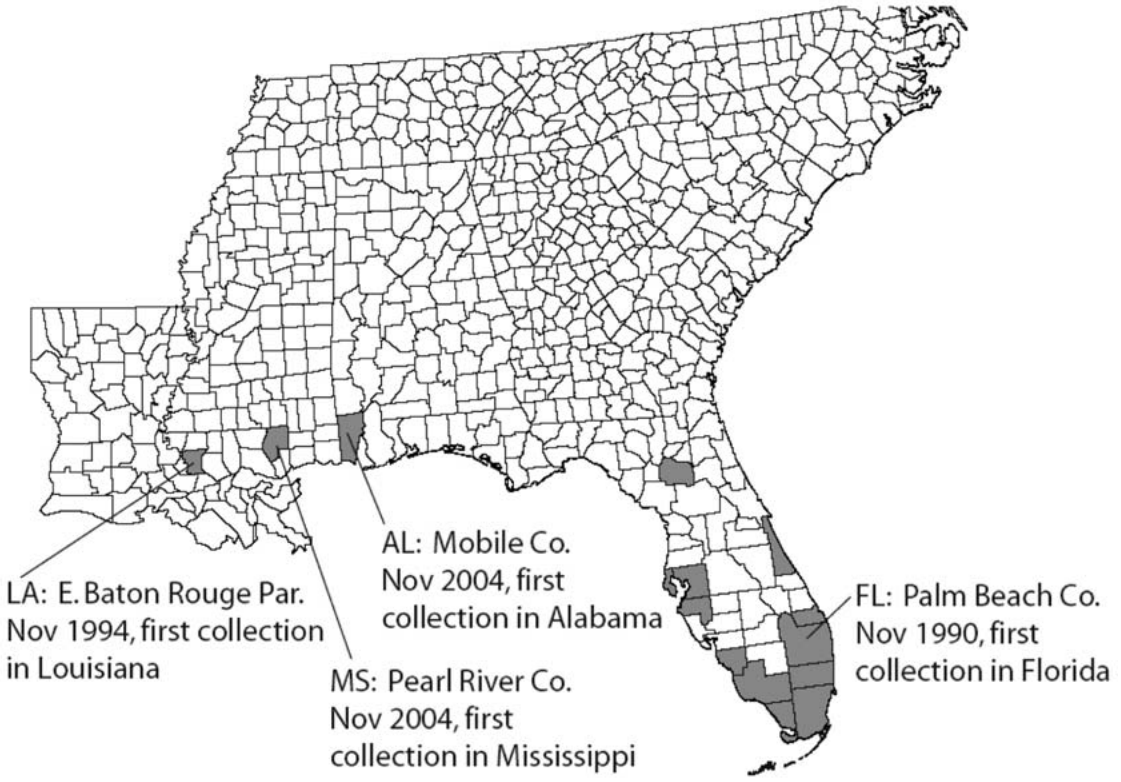

Fig. 2. Current distribution of *Montandoniola moraguesi* in the southeastern United States based on field captures and museum records.

tions persisted in that state, one might expect the LSU collection to contain additional specimens.

The following locality label data are provided for *M. moraguesi* in the continental United States: Alabama: Mobile Co., Mobile, Home Depot Garden Center, 30.674N, 88.224W, 1♀, *Ficus benjamina* infested with *Gynaikothrips uzeli*, 12-XI-2004, D. Boyd (SHL). FLORIDA: ALACHUA CO., 3♂ 1♀, on *Ficus* sp., 21-V-2005, J. Brambila (MIS); Florida: Brevard Co., Indialantic, 1♀, *Ficus retusa*, 23-XII-1991, K. Garret-Kraus (NMNH); Broward Co., Pompano Beach, 10 specimens, pred. on *Gynaikothrips ficorum*, 30-VIII-1991, F. D. Bennett (FSCA); Pompano Bch, 6♂, 6♀, Pred/*Gynaikothrips ficorum*/*Ficus*, 19-XI-1991, F. D. Bennett (FSCA); Pompano Beach, 6 specimens, pred. on *Gynaikothrips ficorum* on *Ficus* sp., 19-XI-1991, F. D. Bennett (FSCA); Collier Co., Everglades City, 2 specimens, ex *Gynaikothrips ficorum* on *Ficus* sp., 3-V-1992, F. D. Bennett (FSCA); Hillsborough Co., Tampa, Busch Gardens, 3♂, 1♀, on *Gynaikothrips ficorum* on *Ficus*, 6-XI-1992, F. D. Bennett (USNM); Lee Co., Ft. Myers, 7♀, host *Gynaikothrips ficorum* on *Ficus*, 2-V-1992, F. D. Bennett (NMNH); Manatee Co., Bradenton, 2♂, 9♀, host *Gynaikothrips ficorum*, on *Ficus*, 8-XI-1992, F. D. Bennett (NMNH); Martin Co., Stuart, 7♂, 8♀, host *Gynaikothrips ficorum*/*Ficus microcarpa*, 12-VIII-1992, F. D. Bennett (NMNH); Miami-Dade Co., Miami, 3 specimens, 143 Ave., ex *Ficus aurea*, 15-V-2001, Ed Putland FSCA# E2001-2090 (FSCA); Miami, SW 137 Ave. and 172 St., 6 specimens, ex *Tabebuia pallida*, 14-X-2002, Holly Glenn, FSCA# E2002-5207 (FSCA); Miami, 68 St. and 102 Ave., 3 specimens, sweep net, 7-IV-2004, J. Durand (FSCA); Miami, 68 St. and 102 Ave., 1 specimen, sweep net, 31-III-2004, J. Durand (FSCA); Goulds, SW 232 Ave., 7 specimens ex *Ficus benjamina*, 21-IV-2004, Eduardo Camero, FSCA# E2004-2958 (FSCA); Homestead 232 St. and 137 Ave., 1 specimen, ex *Ficus microcarpa*, 9-V-2002, Mario Hernandez FSCA# E2002-1796 (FSCA); Miami, 143 Ave., on *Ficus aurea* Nutt., 15-V-2001, Ed Putland, FSCA# E2001-2090 (FSCA); Miami, 68 St. at 102 Ave., 3♂, 2♀, ex *Ficus* sp., 31-III-2004, J. Durand (MIS); Miami, 68 St. at 102 Ave., 3♂, 1♀, ex *Ficus* sp., 7-IV-2004, J. Durand (MIS); Miami, 68 St. at 102 Ave., 7♂, 2♀, ex *Ficus* sp., 17-II-2005, T. Dobbs (MIS); MONROE CO., Key Largo, 91421 U.S. 1, 1♂, 2♀, ex *Ficus* sp. with *Gynaikothrips* sp., 5-IV-2005, T. Dobbs (MIS); Key Largo, 103880 U.S. 1, 3 nymphs ex *Ficus* sp. with *Gynaikothrips* sp., 5-IV-2005, T. Dobbs (MIS); Palm Beach Co., West Palm Beach, 4

specimens, pred. on *Gynaikothrips ficorum* on *Ficus microcarpa*, 23-III-1992, F. D. Bennett (FSCA); West Palm Beach, 5♂, 5♀, on *Gynaikothrips ficorum*/*Ficus microcarpa*, 23-III-1992, F. D. Bennett (NMNH); Pinellas Co., St. Petersburg, 9♂, 11♀, host *Gynaikothrips ficorum* on *Ficus*, 6-XI-1992, F. D. Bennett (NMNH). LOUISIANA: E. Baton Rouge Par., Baton Rouge, 1 specimen, on *Ficus*, 30-IX-1994, J. W. Tessmer (LSU). MISSISSIPPI: PEARL RIVER CO., Poplarville, 1 specimen, pred. *G. uzeli* on *F. benjamina*, 15-XI-2004, D. W. Boyd (SHL); Poplarville, 1 specimen, pred on *G. uzeli* on *F. benjamina*, 14-XII-04, D. Held (SHL); Poplarville, 1 specimen, pred. *G. uzeli* on *F. benjamina*, 05-I-2005, D. W. Boyd (SHL). We were unable to locate the original specimens detected in Palm Beach County in 1990.

Based on data from the Florida State Collection of Arthropods, Florida Department of Agriculture and Consumer Services, Division of Plant Industry, *M. moraguesi* is associated for the first time with *Androthrips ramachandrai* Karny on *F. microcarpa*, *Holopothrips* sp. on *Tabebuia pallida* (Lindl.) Miers, and *Nesothrips* sp. on *Ficus aurea* Nutt. (Table 1).

As stated by Bennett (1995), *M. moraguesi* is widespread in Florida where outdoor plantings of exotic ornamental *Ficus* spp. occur, and has now been detected as far north as Gainesville. In Miami-Dade Co., the bugs were observed in direct association with their thrips prey and were most easily detected by searching for untrimmed *Ficus* hedges with upcurled leaves. The anthocorids enter and remain in the curled leaves while feeding on all life stages of the thrips. Populations of *Gynaikothrips* and *M. moraguesi* were quite high in some instances, yet the plants we observed nearly always had significant new growth and showed no outward signs of ill health aside from moderate leaf distortion.

In Alabama, an adult *M. moraguesi* and associated nymphal exuviae were taken on a *Ficus benjamina* plant in a retail garden center in Mobile Co. No other specimens were located from that state. The plants at the garden center were obtained from a nursery in South Florida, and we assume that the *M. moraguesi* may have hitchhiked with plant material shipped from Florida to Alabama. Two adults and a nymph of *M. moraguesi* were collected in Pearl River Co., Mississippi, on *F. benjamina* plants infested with *G. uzeli*. The plants were traced to local retail nurseries that had, similar to the case in Alabama, originally received plant material from South Florida. An adult was captured in East Baton Rouge Parish, Louisiana, in 1994, two years after intentional releases in neighboring Texas. This record predates by a full decade similar finds in nearby Alabama and Mississippi. Whether the later records reflect a lack of concentrated collecting in the interim is unknown. We found no field populations of *M. moraguesi* in any other states, nor did we find museum specimens from other states. We found no specimens of *M. moraguesi* from California or Texas, although the bug has been introduced into those states to control thrips on *Ficus* plantings (Bennett 1995; Hanlon & Paine 2003). Even though outdoor *Ficus* plantings with suitable thrips hosts are found in other states, we suggest that in the continental United States field populations of *M. moraguesi* currently are restricted to peninsular Florida. Further investigation will clarify this.

Collection of this anthocorid in Alabama and Mississippi on plants shipped from Florida indicates its potential for spread through commercial trade. Its establishment along the Gulf Coast could provide needed biological control of *G. ficorum* and *G. uzeli*. However, *M. moraguesi* has been implicated in biotic interference in at least two cases (Reimer 1988; Bennett 1995; Hanlon & Paine 2003) and potentially can feed on thrips being used for the biological control of weed species.

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The authors express gratitude to the following individuals for checking their respective institutional collections for specimens of *M. moraguesi*: Chris Baptista, Arizona Department of Agriculture; Cheryl Barr, University of California, Berkeley; Victoria Bayless, Louisiana State Arthropod Museum; Charles Bellamy, California Department of Food and Agriculture; Paisley Cato, San Diego Natural History Museum; Wayne Clark, Auburn University; Susan Halbert, Florida State Collection of Arthropods; Thomas Henry, National Museum of Natural History; Steven Heydon, University of California, Davis; John Lattin, Oregon State University; Tamera Lewis, USDA, ARS, Wapato, WA; Carl Olsen, University of Arizona; Norman Penny, California Academy of Sciences; Edward Riley and Joseph Schaffner, Texas A&M University. In addition, we thank Julieta Brambila, Susan Halbert, Thomas Henry, John Lattin, and A. G. Wheeler, Jr. for suggesting improvements to the manuscript, Michael Ferro, Louisiana State Arthropod Museum, for the photograph of *M. moraguesi*, Thomas Henry for taxonomic support, and Susan Halbert for providing *M. moraguesi* host records in Florida.

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DEVELOPING AND EVALUATING TRAPS FOR MONITORING *SCIRTOTHRIPS DORSALIS* (THYSANOPTERA: THRIPIDAE)

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ABSTRACT

Scirtothrips dorsalis (Hood) (Thysanoptera: Thripidae) is a recently identified invasive pest to the Caribbean and poses a significant threat to agriculture and trade in the region. Methods are needed to detect the presence and to monitor populations of this pest so that it can be effectively managed. Three different CC trap base colors (blue, yellow, and white) with or without dichlorvos as a killing agent, and a newly developed and named the Blue-D trap were studied in Taiwan and St. Vincent for attraction and capture of *S. dorsalis*. In lemons in Taiwan, mean numbers of *S. dorsalis* caught in Blue-D traps were greater compared with dichlorvos cube modified CC traps. In St. Vincent chili pepper plantings, the Blue-D traps caught more *Thrips palmi* (Karny), *Frankliniella* sp., and *Microcephalothrips abdominalis* (Crawford) than dichlorvos cube modified CC traps. More *Frankliniella intonsa* (Trybom), *Megalurothrips usitatus* (Bagnall), *T. palmi*, *Frankliniella* sp., and *M. abdominalis* were caught in blue and white base CC traps than yellow base CC traps. Average captures per CC trap per week were 0.07 and 0.02-0.09 *S. dorsalis* in Taiwan and St. Vincent, respectively. There were no differences in *S. dorsalis* captures in white, blue, or yellow base CC traps. The average weekly *S. dorsalis* catch for yellow sticky card traps was 19.8. CC traps can be used for detection of *S. dorsali* and collecting intact *S. dorsalis* for taxonomic and genetic determinations when a few of the species are found in a large commercial production area. Yellow sticky traps can be used for monitoring *S. dorsalis* populations. A combination detecting system of visual observation, yellow sticky traps, and CC traps may be an effective *S. dorsalis* population detecting and monitoring system.

Key Words: *Scirtothrips dorsalis*, *Frankliniella occidentalis*, *Thrips palmi*, CC traps, Caribbean area

RESUMEN

Scirtothrips dorsalis (Hood) (Thysanoptera: Thripidae) es una plaga invasora recien identificada en el Caribe y representa una amenaza significativa a la agricultura y comercio de la región. Es necesario desarrollar métodos para detectar la presencia de esta plaga y realizar un monitoreo de su poblacion para lograr un manejo mas eficaz. Trampas de CC de tres colores diferentes (azul, amarilla, y blanca) con o sin el pesticida dichlorvos como agente para matar, y una trampa recién desarrollada y nombrada 'Blue-D' fueron estudiadas en Taiwan y St. Vincent para ver su habilidad para atraer y capturar *S. dorsalis*. En limones en Taiwan, el promedio del número de *S. dorsalis* capturados en las trampas de Blue-D fue mas alto comparado con las trampas de CC cubicas modificadas con dichlorvos. En siembras del chile verde en St. Vincent, la trampa de Blue-D capturo mas *Thrips palmi* (Karny), *Frankliniella* sp., y *Microcephalothrips abdominalis* (Crawford) que la trampa de CC cubica modificada con dichlorvos. Habian un mayor número de *Frankliniella intonsa* (Trybom), *Megalurothrips usitatus* (Bagnall), *T. palmi*, *Frankliniella* sp. y *M. abdominalis* capturadas en trampas de CC con la base de color azul o blanco que en las trampas con la base amarilla. El promedio de los *S. dorsalis* capturados en las trampas de CC por semana fue 0.07 y 0.02-0.09 en Taiwan y St. Vincent, respectivemente. No hubo ninguna diferencia en el número de *S. dorsalis* capturados en trampas de CC con la base de color blanco, azul o amarilla. El promedio semanal de los *S. dorsalis* capturados con trampas de tarjetas pegajosas amarillas fue 19.8. Se puede usar las trampas de CC para detectar la presencia de *S. dorsalis* y recolectar especimenes de *S. dorsalis* intactos para su identificación taxonómica y genética cuando solamente se encuentran pocos especies en las áreas grandes de producción comercial. Se puede usar las trampas amarillas pegajosas para realizar un monitoreo de la población de *S. dor-*

salis. Un sistema de detección que combine la observación visual, las trampas amarillas pegajosas, y las trampas de CC puede ser efectivo para detectar y realizar monitoreos de poblaciones de *S. dorsalis*.

Scirtothrips dorsalis (Hood) was described in 1916 as a new species collected from castor bean and chili plants in Coimbatore, Southern India (Hood 1919). *S. dorsalis* are polyphagous pests that are widespread in habitat ranging from temperate to tropical climate regions in Pakistan, Japan, and Australia (Mound & Palmer 1981). Primary hosts are onion, cashew nut, tea, chili, cotton, tomato, mango, tobacco, and castor bean. The insect has been reported by the Animal Plant Health Inspection Service (APHIS) as one of the thirteen most important pest species that could become a serious threat to United States (US) agricultural crops if it becomes established in the country (USDA-APHIS 2004). The Florida Nurserymen and Growers Association (FNGA) also consider *S. dorsalis* as an exotic pest with high potential to damage their industry if it becomes established in the state (FNGA 2003). Since 1984, USDA-APHIS inspectors at various US ports of entry have reported finding live *S. dorsalis* a total of 89 times from imported plant materials of 48 plant taxa (USDA 2003). On July 6, 2003, a Plant Protection and Quarantine (PPQ) officer in Miami, FL intercepted live *S. dorsalis* on chili peppers shipped from St. Vincent, a Caribbean island nation (Skarlinsky 2003). Subsequently, surveys of St. Vincent and St. Lucia confirmed the presence of *S. dorsalis* on both islands (Ciomperlik & Seal 2004). Thrips samples collected from both islands were catalogued and submitted to the USDA-Agricultural Research Service (ARS) Systematic Entomology Laboratory, Beltsville, MD, and the Australian Commonwealth Scientific & Industrial Research Organization (CSIRO) Entomology Laboratory, Canberra, Australia.

A pest risk assessment by Venette & Davis (2004) indicates that the potential geographic distribution of *S. dorsalis* in the U.S. ranges from the northeastern Atlantic area to Minnesota in the northern latitudes and to Texas in the south. Meissner et al. (2005) indicates that permanent establishment would likely be limited to southern and West Coast states. The species also seems capable of spreading throughout the entire Caribbean region. So far, it has become established on the Caribbean islands of St. Lucia, St. Vincent (Ciomperlik & Seal 2004), and Trinidad (USDA Offshore Pest Information System 2004).

Current survey, detection, and monitoring methods for *S. dorsalis* are laborious and require significant manpower and technical training. Most species in the genus *Scirtothrips* are pale in color, minute, and must be cleared and slide mounted for species identification. In addition, the genus is confused taxonomically. The names *Heliothrips minutissimus* (Bagnall), *Anaphothrips andreae* (Karny), *Scirtothrips padmae* (Ramakrishna), and *S. fragaiae* (Girault) appear in the literature but are now considered to be synonyms of *S. dorsalis* (Mound & Palmer 1981). Ongoing research and development methods that incorporate Polymerase Chain Reaction-Restriction Fragment Length Polymorphism (RFLP-PCR) genetic techniques (Toda & Komazaki 2002) are being conducted to explore the ribosomal ITS2 DNA regions that can be used to rapidly distinguish between thrips species. These methods require that individual insect samples be whole and undamaged, free of foreign contaminating substances, and preferably without contaminant DNA. Based on these requirements, sticky traps often used for thrips detection and monitoring are unsuitable.

To obtain specimens for taxonomic and genetic studies, terminal leaf samples can be collected in ziplock bags and washed with ethanol to obtain full intact specimens (Ciomperlik & Seal 2004). The plastic cup trap (named CC trap) (Fig. 1) also collects intact *S. dorsalis* specimens. It can be installed in a commercial production area where the pest has been found or suspected and serviced periodically for long periods of time. The CC trap was designed and validated for monitoring sweetpotato whitefly, *Bemisia tabaci* (Gennadius) B-biotype, populations. Trap design was based on the sweetpotato whitefly attraction to the color yellow, flight patterns approaching plants, and landing behavior (Chu et al. 1995; Chu & Henne-

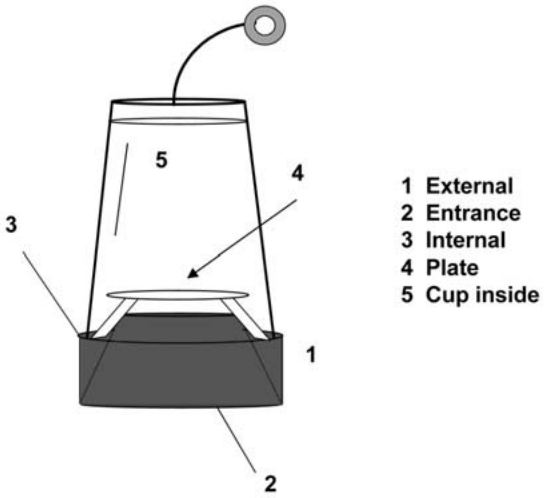

Fig. 1. CC trap with number trap surface identifications.

berry 1998). The white base CC traps caught more *S. dorsalis* and *Thrips palmi* (Karny) in a peanut field in India in 1996 than yellow base traps (Chu et al. 2000). To extend the usefulness of the CC traps for detection and monitoring *S. dorsalis*, *T. palmi*, and other thrip species under Caribbean island conditions, we are studying different methods to increase trap efficacy.

White, yellow, and blue colors have been reported attractive to *S. dorsalis*, *T. palmi*, or *F. occidentalis* (Beavers et al. 1971; Gillespie & Vernon 1990; Cho et al. 1995; Tsuchiya et al. 1995; Chu et al. 2000; Hoddle et al. 2002; Chen et al. 2004). Chu et al. (2005) have modified CC whitefly traps for detecting and monitoring western flower thrips.

Objectives of the current study were (1) to evaluate CC thrip trap modification with a killing agent and a specimen preservative, (2) to evaluate a modification of a commercially available dichlorvos strip package for use as a thrips trap, named the Blue-D trap in this report, and (3) to evaluate sticky card traps.

Materials and Methods

Comparison of CC and Blue-D traps

The study was conducted in commercial farms with randomized complete block designs with 15 and five replicates in Taiwan and St. Vincent, respectively. Treatments were re-randomized weekly in St. Vincent, but not in Taiwan. The four CC trap treatments in Taiwan were trap base colors (white, blue, and yellow with a 1 cm^2 dichlorvos cube and 15 ml, 10% ethylene glycol) and the Blue-D trap. In St.Vincent, the three trap base colors with or without dichlorvos cube and with or without ethylene glycol made a total of 12 treatments. Blue-D trap was the 13th treatment. The dichlorvos cubes in CC traps were not replaced during the experimental periods. The ethylene glycol treatment was used to preserve thrip specimens. The CC traps were serviced weekly, disassembled in the field, rinsed with 20 ml 85% ethanol to dislodge insects that were retained in the trap bases, and stored in labeled glass vials for identification in the laboratory.

The Blue-D traps were Hot Shot® No-Pest® Strip dispensers (United Industry Corp., St. Louis, Mo.) fitted with plastic bags attached to the dispenser bottoms for collecting dead insects. Vertically oriented blue plastic strips (two 2.5-cm wide strips spaced at 2.5 cm apart) were attached inside the front and back surfaces of the dichlorvos dispensers packages (Fig. 2). The Blue-D traps were replaced weekly.

Experiment 1. Taiwan (dry season). The experiment was conducted in a 0.6-ha lemon (*Citrus limon* L., cv. Eureka) orchard for eight weeks from 26 November 2004 to 30 January 2005 in Neipu, Taiwan. The traps were suspended in trees 1.9 m above the ground.

Fig. 2. Dichlorvos dispenser modification with blue stripe and sample collecting bag placed in the top canopy of a lemon tree in Neipu, Pingtung County, Taiwan.

Experiment 2. St. Vincent (wet season). The experiment was conducted about one mile inland from Caribbean sea in Georgetown, St. Vincent Island in two (~0.2 ha each) geographically separated chili pepper (*Capsicum chinense* L.) fields. Plants were set 1 m within and between row spacings in both fields. Plants in one field were Scotch Bonnet variety and in the other field the West Indies Red variety. Traps were placed 1 m apart on wooden stakes placed within the plant rows. The trap bases were located about 22 cm below the tallest plant terminals. The experiment was conducted for six weeks from 14 October to 29 November, 2004.

Experiment 3. St. Vincent (dry season). The experiment was conducted in two Scotch Bonnet variety (~0.2 ha each) fields, as described in Experiment 2. The experiment was conducted for six weeks from 23 March to 4 May, 2005.

All thrips in the samples were identified and counted. *Scirtothrips dorsalis* was readily separated from the other species by the small size (0.7-1.0 mm), pale yellow color, and the presence of microtrichia extending along the median area of the abdominal sternites (Hoddle & Mound 2003). The remaining species were separated from each other

by characters found in Nakahara's key to Thripidae (unpublished). Representative individuals of each thrips species were slide mounted to confirm the species identity. Voucher specimens from St. Vincent were deposited in the USDA-ARS Systematic Entomology Laboratory and in the St. Vincent Ministry of Agriculture and Fisheries.

Seasonal Weather during the Wet and Dry Seasons in St. Vincent, 2004-2005

Daily rainfall data and air temperatures during both seasons were obtained from weather station records housed at Rabacca Field Station in Georgetown, St. Vincent. The weather station was located about 0.4 km from the experimental chili pepper fields. CC trap captures were examined in relation to average rainfall and temperature in the wet and dry seasons.

Comparison of Sticky Card Trap Colors (Dry Season)

Experiment 4. The experiment was conducted during the dry season in 2005 in the same commercial pepper fields in St. Vincent described for Experiment 3. The thrips trap captures compared sticky card traps with the CC and Blue-D trap captures. The sticky card traps were 10.0 by 10.5 cm in size. White sticky card traps were constructed by coating both sides with brush-on Tanglefoot® formula (Tanglefoot Co., Grand Rapids, MI). Blue sticky card traps of the same dimensions were Takitrap® obtained commercially (Oecos Ltd., Kimpton, Hertfordshire, England). Yellow sticky card traps also of the same dimensions were custom made commercially (Olson Products, Medina, OH). The sticky card traps were placed in chili pepper rows 1 m apart. Traps were oriented vertically with wire loops attached to 25 cm long wooden stakes. Traps were placed 5-10 cm above the plant terminals.

Statistical Analysis

Numbers of thrips caught were averaged over sampling periods for each experiment. Data were analyzed by *t*-tests, ANOVA orthogonal comparisons, or three factor factorial analysis (Anonymous 1989). Means were separated by Tukey's HSD.

RESULTS

Experiment 1. Comparison of CC and Blue-D traps in Taiwan (dry season). Blue-D traps caught more *S. dorsalis* than the CC traps ($F = 4.8$, $df = 1, 58$, $P = 0.034$). Mean captures for *F. intonsa* or *T. hawaiiensis* (Morgan) for the two trap types were not statistically different (Table 1). Catches of *S. dorsalis* by the three different color CC trap bases were not significantly different. White base CC traps caught more *T. hawaiiensis* ($F = 14.5$, $df = 2, 28$, $P = <0.001$), and blue base CC traps caught more *M. usitatus* ($F = 49.0$, $df = 2, 28$, $P = <0.001$) compared with other trap base colors. White and blue base CC traps caught more *F. intonsa* ($F = 7.3$, $df = 2, 28$, $P = 0.028$) compared with yellow base CC traps. The four thrips species are considered economic pests in Taiwan (Chang 1995).

Experiment 2. Comparison of CC and Blue-D traps in St. Vincent (wet season). Blue-D traps caught more *T. palmi*, *Frankliniella* sp., and *M. abdominalis* than CC traps ($F = 42.4 – 99.2$, $df = 1, 58$, $P = <0.001$). Mean captures of *S. dorsalis* for the two trap types were not significantly different. Captures of *S. dorsalis* in CC traps for different trap base colors were not significantly different. Blue and white base CC traps caught more *T. palmi*

TABLE 1. SEASONAL MEANS (±SE) THRIPS CAUGHT IN A LEMON ORCHARD IN NEIPU, TAIWAN, DRY SEASON, 26 NOVEMBER 2004 TO 30 JANUARY 2005 (EXPERIMENT 1).

	Mean numbers/trap/week			
	S. dorsalis	*F. intonsa*	*T. hawaiiensis*	*M. usitatus*
Trap type				
Blue-D[a]	0.34 ± 0.20 a[c]	0.50 ± 0.33 a	1.78 ± 1.39 a	0.44 ± 0.17 a
CC traps	0.07 ± 0.02 b	0.11 ± 0.02 a	0.36 ± 0.05 a	0.76 ± 0.17 a
F, P	4.8, 0.034	3.9, 0.053	3.0, 0.089	3.0, 0.089
CC trap (base color)				
White[b]	0.10 ± 0.03 a	0.10 ± 0.02 ab	0.63 ± 0.09 a	0.18 ± 0.04 b
Blue	0.02 ± 0.01 a	0.20 ± 0.05 a	0.28 ± 0.06 b	2.07 ± 0.28 a
Yellow	0.09 ± 0.04 a	0.03 ± 0.01 b	0.18 ± 0.04 b	0.03 ± 0.03 b
F, P	3.7, 0.047	7.3, 0.028	14.5, <0.001	49.0, <0.001

[a]Dichlorvos dispenser plus blue stripes (Blue-D).
[b]CC-trap base color with dichlorvos killing agent and ethylene glycol preservative.
[c]Means in a column not followed by the same letter are significantly different by orthogonal comparison for Blue-D vs. CC traps, $df = 1, 58$ and by Tukey's HSD for CC traps, $df = 2, 28$.

and *Frankliniella* sp. (F = 4.1 and 5.3, df = 2, 44, P = 0.024 and 0.009, respectively) than yellow base CC traps. Blue base CC traps caught more *M. abdominalis* than white and yellow base CC traps (F = 99.2, df = 2, 44, P = 0.003). Dichlorvos cubes in CC traps increased captures of all thrips species (F = 6.0 – 20.6, df = 1, 44, P = 0.018 – <0.001) except *S. dorsalis*. Ethylene glycol in the CC trap bases had no effect on trap catch numbers. However, thrips captured in ethylene glycol equipped traps were well preserved, with less damage to antennae and less desiccation than traps without ethylene glycol.

There were significant treatment interactions for CC trap base colors and dichlorvos treatments for *T. palmi* trap catches (F = 6.6, df = 2, 44, P = 0.003), but not for the three other thrips species (Table 2). Thrips captures for the ethylene glycol treatment, or the interactions with CC trap base color and dichlorvos were not significantly different.

Frankliniella sp. captures were identified by Systematic Entomology Laboratory as *Frankliniella cephalica* (Crawford) and *Frankliniella insularis* (Franklin).

Experiment 3. Comparison of CC and Blue-D traps in St. Vincent (dry season). Mean numbers of *T. palmi*, *Frankliniella* sp., and *M. abdominalis* caught in Blue-D traps were greater compared with CC traps (F = 8.2 – 10.4, df = 1, 58, P = 0.002 – 0.006). Mean captures of *S. dorsali* were not significantly different for the two trap types (Table 3). dichlorvos cubes in CC traps increased captures of all four thrips species (F = 8.6 – 72.2, df = 1, 44, P = 0.005 – <0.001). On average, blue and white base CC traps caught more *T. palmi*, *Frankliniella* sp., and *M. abdominalis* than yellow base CC traps (F = 9.5 – 16.7, df = 2, 44, P = 0.002 – <0.001). The addition of ethylene glycol in traps resulted in greater captures of *S. dorsalis*, *Frankliniella* sp., and *M. abdominalis* (F = 7.4 – 10.5, df = 1, 44, P = 0.009 – 0.002), than the mean captures of *T. palmi*. Blue and white base CC traps with ethylene glycol caught more *Frankliniella* sp. (F = 4.0, df = 2, 44, P = 0.024), but not the other three thrips species. There were no significant differences in thrips captures for other treatment interactions.

TABLE 2. SEASONAL MEANS (±SE) OF THRIPS CAUGHT IN TRAPS IN COMMERCIAL CHILI PEPPER FIELDS, GEORGETOWN, ST. VINCENT, WET SEASON, 14 OCTOBER TO 29 NOVEMBER (EXPERIMENT 2.)

	Mean numbers/trap/week			
	S. dorsalis	*T. palmi*	*Frankliniella* sp.	*Microcephalothrips abdominalis*
Trap type				
Blue-D[a]	0.00 ± 0.00 a[b]	0.47 ± 0.16 a	0.71 ± 0.17 a	0.82 ± 0.10 a
CC traps	0.02 ± 0.01 a	0.08 ± 0.01 b	0.11 ± 0.03 b	0.15 ± 0.02 b
F, *P*	1.3, 0.259	42.4, < 0.001	48.9, < 0.001,	99.2, < 0.001
CC trap (base color)				
White	0.02 ± 0.01 a	0.09 ± 0.03 a	0.10 ± 0.03 ab	0.11 ± 0.04 b
Blue	0.03 ± 0.01 a	0.10 ± 0.03 a	0.20 ± 0.06 a	0.24 ± 0.04 a
Yellow	0.02 ± 0.01 a	0.03 ± 0.01 b	0.03 ± 0.02 b	0.09 ± 0.03 b
F, *P*	<0.1, None	4.1, 0.024	5.3, 0.009	6.9, 0.003
Dichlorvos in CC traps				
Yes	0.02 ± 0.01 a	0.12 ± 0.02 a	0.17 ± 0.05 a	0.22 ± 0.03 a
No	0.03 ± 0.01 a	0.03 ± 0.01 b	0.06 ± 0.02 b	0.07 ± 0.02 b
F, *P*	0.2, None	17.5, < 0.001	6.0, 0.018	20.6, < 0.001
Base-dichlorvos				
White-yes	0.02 ± 0.01 a	0.17 ± 0.05 a	0.13 ± 0.05 a	0.15 ± 0.06 a
White-no	0.02 ± 0.02 a	0.02 ± 0.01 b	0.08 ± 0.04 a	0.07 ± 0.03 a
Blue-yes	0.02 ± 0.01 a	0.18 ± 0.03 a	0.32 ± 0.11 a	0.36 ± 0.05 a
Blue-no	0.03 ± 0.01 a	0.03 ± 0.02 b	0.09 ± 0.04 a	0.11 ± 0.04 a
Yellow-yes	0.02 ± 0.01 a	0.02 ± 0.02 b	0.06 ± 0.04 a	0.16 ± 0.04 a
Yellow-no	0.03 ± 0.01 a	0.04 ± 0.01 a	0.00 ± 0.00 a	0.03 ± 0.01 a
F, *P*	<0.1, None	6.6, 0.003	1.6, 0.214	2.3, 0.108

[a]Dichlorvos dispenser plus blue stripes (Blue-D).

[b]Means in a column of the same variable not followed by the same letter are significantly different by orthogonal comparison for Blue-D vs. CC traps, and df = 1, 58, and by Tukey's HSD for CC traps, and df = 1 or 2, 44. Means of three way interactions were not significantly different. Ethylene glycol treatments and other interactions were not statistically different.

TABLE 3. SEASONAL MEANS (±SE) OF THRIPS CAUGHT IN COMMERCIAL CHILI PEPPER FIELDS, GEORGETOWN, ST. VINCENT, DRY SEASON, 23 MARCH TO 4 MAY 2005 (EXPERIMENT 3).

	Mean numbers/trap/week			
	S. dorsalis	*T. palmi*	*Frankliniella* sp.	*Microcephalothrips abdominalis*
Trap type				
Blue-D[a]	0.05 ± 0.03 a[b]	1.06 ± 0.33 a	0.21 ± 0.09 a	0.33 ± 0.06 a
CC trap	0.09 ± 0.02 a	0.49 ± 0.08 b	0.08 ± 0.02 b	0.17 ± 0.03 b
F, P	0.7, None	10.4, 0.002	8.7, 0.005	8.2, 0.006
CC trap (base color)				
White	0.06 ± 0.02 a	0.53 ± 0.13 a	0.08 ± 0.02 ab	0.16 ± 0.04 ab
Blue	0.13 ± 0.04 a	0.78 ± 0.16 a	0.14 ± 0.04 a	0.25 ± 0.06 a
Yellow	0.08 ± 0.02 a	0.17 ± 0.04 b	0.02 ± 0.01 b	0.10 ± 0.03 b
F, P	2.3, 0.111	16.7, <0.001	9.5, <0.001	7.2, 0.002
Dichlorvos in CC traps				
Yes	0.13 ± 0.03 a	0.82 ± 0.12 a	0.14 ± 0.03 a	0.31 ± 0.04 a
No	0.05 ± 0.01 b	0.17 ± 0.03 b	0.02 ± 0.01 b	0.04 ± 0.01 b
F, P	8.6, 0.005	55.3, <0.001	33.9, <0.001	72.2, <0.001
Base-dichlorvos				
White-yes	0.08 ± 0.04 b	0.89 ± 0.18 b	0.13 ± 0.03 b	0.28 ± 0.06 b
White-no	0.04 ± 0.02 b	0.18 ± 0.07 c	0.03 ± 0.02 bc	0.03 ± 0.03 c
Blue-yes	0.23 ± 0.06 a	1.35 ± 0.19 a	0.26 ± 0.06 a	0.46 ± 0.07 a
Blue-no	0.03 ± 0.01 b	0.22 ± 0.06 c	0.02 ± 0.01 c	0.04 ± 0.03 c
Yellow-yes	0.08 ± 0.02 b	0.22 ± 0.06 c	0.04 ± 0.02 bc	0.18 ± 0.05 bc
Yellow-no	0.08 ± 0.03 b	0.12 ± 0.04 c	0.01 ± 0.01 c	0.03 ± 0.01 c
F, P	4.6, 0.015	11.7, <0.001	8.3, 0.001	6.4, 0.004
Ethylene glycol in CC traps				
Yes	0.13 ± 0.02 a	0.51 ± 0.09 a	0.11 ± 0.03 a	0.22 ± 0.04 a
No	0.05 ± 0.02 b	0.48 ± 0.12 a	0.05 ± 0.02 b	0.12 ± 0.04 b
F, P	7.5, 0.009	0.2, None	7.4, 0.009	10.5, 0.002
Base-ethylene glycol				
White-yes	0.10 ± 0.04 a	0.57 ± 0.15 a	0.10 ± 0.03 ab	0.24 ± 0.07 a
White-no	0.03 ± 0.02 a	0.50 ± 0.21 a	0.06 ± 0.03 b	0.08 ± 0.03 a
Blue-yes	0.15 ± 0.05 a	0.74 ± 0.21 a	0.21 ± 0.07 a	0.27 ± 0.08 a
Blue-no	0.11 ± 0.05 a	0.83 ± 0.26 a	0.07 ± 0.03 b	0.23 ± 0.09 a
Yellow-yes	0.13 ± 0.02 a	0.23 ± 0.06 a	0.02 ± 0.01 b	0.16 ± 0.05 a
Yellow-no	0.03 ± 0.01 a	0.11 ± 0.04 a	0.03 ± 0.02 b	0.05 ± 0.02 a
F, P	0.4, None	0.5, None	4.0, 0.024	1.4, 0.239

[a]Dichlorvos dispenser plus blue stripes (Blue-D).

[b]Means in a column of the same variable not followed by the same letter are significantly different by orthogonal comparison for Blue-D vs. CC traps, and *df* = 1, 58, and by Tukey's HSD for CC traps, and *df* = 1 or 2, 44. Means of three way interactions were not significantly different. Ethylene glycol treatments and other interactions were not statistically different.

Seasonal Weather Effects on CC Trap Catches during the Wet and Dry Seasons in St. Vincent, 2004-2005

CC trap captures were 4.5 and 6.1 fold greater for *S. dorsalis* and *T. palmi*, respectively, during the dry season compared with the wet season. Rainfall averaged 1.1 mm per day during the dry season and 18.0 mm per day during the wet season (Table 4). Air temperatures in the dry season was 1.3°C higher compared with the wet season.

Experiment 4. Comparison of Sticky Card Trap Colors (Dry Season). Significantly more *S. dorsalis* were caught on yellow sticky card traps compared with blue sticky card traps. Yellow and blue sticky card traps caught more *S. dorsalis* than white sticky card traps (Table 5). More *T. palmi*, *Frankliniella* sp. and *M. abdominalis* were caught on blue sticky card traps compared with white and yellow sticky card traps.

TABLE 4. SEASONAL MEAN (±SE) RAINFALL, AIR TEMPERATURE, AND CC TRAP CAPTURES OF THRIPS SPECIES DURING THE WET AND DRY SEASONS IN ST. VINCENT, 2004-2005.

Season	Mean mm/day	Rainfall total (mm)	Rainy days total	Air temperature °C	Mean numbers/trap/week[a]			
					S. dorsalis	*T. palmi*	*Frankliniella* sp.	*Microcephalothrips abdominalis*
Wet (W)	18.2 ± 4.8	855.1	34/47	28.4 ± 0.03	0.02 ± 0.00 b	0.08 ± 0.01 b	0.11 ± 0.03 a	0.15 ± 0.02 a
Dry (D)	1.1 ± 0.4	48.1	10/43	29.7 ± 0.01	0.09 ± 0.01 a	0.49 ± 0.09 a	0.08 ± 0.01 a	0.17 ± 0.02 a
t, *P*					57.8, <0.001	22.3, 0.002	0.8, None	0.6, None
D/W ratio	0.58	0.47	0.23	1.05	4.5	6.1	1.4	1.1

[a]Means in a column followed by the same letter are not significantly different by *t*–test, *df* = 1.

DISCUSSION

Blue-D traps caught more *S. dorsalis* than the CC traps in Taiwan, but approximately equal numbers in St. Vincent. Similarly, Blue-D traps consistently caught more of the other three thrips species in the study compared with the CC trap. Overall, the addition of dichlorvos cubes increased CC trap captures of *S. dorsalis* in St. Vincent. The blue base CC trap with dichlorvos cubes caught more *S. dorsalis* than the other treatment combinations only during the dry season in St. Vincent. Unfortunately, previous trap studies conducted in India on *S. dorsalis* did not include blue base CC trap comparisons with white and yellow base traps (Chu et al. 2000). The addition of ethylene glycol to CC traps increased trap catches of *S. dorsalis* and *M. abdominalis* during the dry season in St. Vincent. The addition of ethylene glycol resulted in better preserved specimens for taxonomic and genetic studies.

Numbers of *S. dorsalis* captured in CC traps with dichlorvos were low in both Taiwan and St. Vincent. We reported earlier that blue sticky card traps caught more *F. occidentalis* in a broccoli field than yellow sticky card traps (Chen et al. 2004). Blue sticky card traps also captured greater numbers of *T. palmi*, *Frankliniella* sp., and *M. abdominalis* than yellow or white traps in the current studies. Our results from St. Vincent indicate that yellow sticky card traps were more attractive to *S. dorsalis* than white or blue sticky card traps. Similarly, Hoddle et al. (2003) reported that *Scirtothrips perseae* (Nakahara) was more attracted to yellow than white or blue sticky card traps.

The Blue-D trap did not consistently capture greater numbers of *S. dorsalis* than CC traps. Its potential toxicity in the environment is of concern. Although the CC trap captures fewer *S. dorsalis*, the quality of the captured specimens is high. They are easily recovered from the trap and stored in ethanol for later taxonomic and genetic analysis. Yellow sticky traps capture more thrips than the CC traps but they also capture a large number of non-target insects. In addition, thrips that are captured on the sticky trap are not easily removed and stored for later studies. Sticky traps seem to be less labor intensive, require less component assembly and therefore less expertise in trap placement than the CC traps.

Seal et al. (2005) have determined from direct plant sampling that economic damage to chili peppers by *S. dorsalis* occurs at densities of 0.5 to 2 individuals (larvae or adults) per terminal leaf. This sampling method requires nine samples per 24-48 m^2 area in order to achieve the 90% precision level. This method may be too labor intensive to use in large scale survey and detection efforts. Alternatively, visual observation

TABLE 5. SEASONAL MEANS (±SE) OF THRIPS CAUGHT ON WHITE, BLUE, AND YELLOW STICKY CARD TRAPS IN COMMERCIAL CHILI PEPPER FIELDS, GEORGETOWN, ST. VINCENT, DRY SEASON, 23 MARCH TO 4 MAY 2005 (EXPERIMENT 4).

Sticky trap color	Mean numbers/trap/week[a]			
	S. dorsalis	*T. palmi*	*Frankliniella* sp.	*Microcephalothrips* sp.
White	1.41 ± 0.11 b	8.04 ± 1.45 b	2.08 ± 0.34 b	4.39 ± 0.57 b
Blue	3.72 ± 0.37 b	27.11 ± 2.20 a	8.75 ± 0.85 a	21.40 ± 1.79 a
Yellow	14.10 ± 1.06 a	7.38 ± 0.62 b	1.73 ± 0.18 b	4.30 ± 0.45 b
F, *P*	111.4, <0.001	57.411.7, <0.001	50.0, <0.001	77.6, <0.001

[a]Means in a column not followed by the same letter are significantly different by Tukey's HSD, and *df* = 2 or 18.

for plant damage symptoms like curled, deformed, or yellow leaves coupled with placing sticky card traps can be utilized as a preliminary detection tool. Positive detections would then be followed by direct plant sampling to capture large number of individual specimens for taxonomic verification. APHIS guidelines for survey are based on the principle of finding one *S. dorsalis* in a suspected area. The guidelines suggest 2,280 CC traps for initial survey that will be placed in one square mile areas for detecting *S. dorsalis* (USDA-aphis, 2004). If one or more *S. dorsalis* is found the second phase of survey the survey area will be expanded to the eight surrounding square miles. The presence of a single *S. dorsalis* in the second survey will lead to an expansion of the survey area to 80 surrounding square miles for the third phase of survey. Results of our studies estimate that CC traps would catch 46 and 205 for wet and dry seasons, respectively. These would translate to the captures of 46 and 205 *S. dorsalis* in CC traps for the initial survey, 148 and 666 for the second survey, and 1069 and 4813 for third phase of survey during wet and dry seasons, respectively, in St. Vincent.

Current methods employed for detection of *S. dorsalis* are inefficient as demonstrated in the present report. Studies of *S. dorsalis* behavior, including the development of attractants and pheromones as potential lures, are being conducted to develop more efficient trap systems for detection and monitoring of this insect pest.

During preparation of this manuscript, *S. dorsalis* was detected on roses in Palm Beach, FL and in multiple retail garden centers on hot pepper seedlings by the Florida Department of Agriculture and Consumer Services (FDACS) (Wayne Dixon, pers. comm.). Further surveys of retail garden centers in the Lower Rio Grande Valley of Texas likewise revealed the presence of this new invasive species on hot pepper seedlings (M. Ciomperlik, unpublished data). Specimens were confirmed as *Scirtothrips dorsalis* by the USDA ARS Systematic Entomology Laboratory. The current distribution of *S. dorsalis* in the Caribbean is limited to a few islands. It has recently invaded the US, and is expected to spread over time through agricultural trade and tourism (Venette & Davis 2004; Meissner et al. 2005). These observations also indicate an alarming potential for rapid spread of this pest thrip species through interstate movement of ornamentals and plant seedlings in the US. The potential impact of this thrips on agriculture in the United States alone has been estimated at approximately $3.6 to $6.0 billion a year (Lynn Garrett, USDA APHIS PPQ CPHST, pers. comm.). Effective survey and detection methods are needed to monitor the spread, and manage populations, of *S. dorsalis* both in the Caribbean and the US.

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EGG HATCHING OF *PERIPHYLLUS CALIFORNIENSIS* (HEMIPTERA: APHIDIDAE) IN TWO MICROHABITATS WITH DIFFERENT BUDBURST PHENOLOGIES

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ABSTRACT

Egg hatching of the maple aphid, *Periphyllus californiensis* Shinji, was observed on saplings of *Acer amoenum* Carriere in two microhabitats, i.e., the understory of a maple stand (a shaded site) and an open area in a nursery (a sunny site), over a 2-year period. Buds of *A. amoenum* opened earlier at the shaded site than at the sunny site and eggs of *P. californiensis* also hatched a little earlier at the shaded site. To test whether oviposition timing or microhabitat characteristics affected the timing of egg hatching, eggs were collected during four periods in December to observe egg hatching in the laboratory. Hatching occurred earlier at the shaded site than at the sunny site only for eggs laid in early December. The duration of egg hatching was shorter for eggs laid earlier compared with those laid later. The duration of the egg stage (estimated as the median oviposition date to the median egg hatching date) was negatively correlated with the time when the eggs were laid. These results suggest that differences in timing of egg hatching between habitats may be affected by the microhabitat and date of oviposition.

Key Words: oviposition, egg duration, host plant phenology, synchrony

RESUMEN

La eclosión de huevos del áfido arce, *Periphyllus californiensis* Shinji, fue observads en renuevos de *Acer amoenum* Carriere en dos micro habitares, o sea, la parte abajo de los árboles de arce (un sitio con sombra) y una área abierta de un vivero (un sitio con sol), durante un período de 2 años. Los brotes de *A. amoenum* abrieron mas temprano en el sitio con sombra que en el sitio bajo el sol y los huevos de *P. californiensis* también esclosionaron un poco mas temprano en el sitio de sombra. Para probar si el tiempo de la oviposición o las características del micro habitares afectaron el tiempo de la eclosión de los huevos, se recolectaron huevos durante cuatro períodos en el mes de diciembre para observar la eclosión de huevos en el laboratorio. La eclosión fue mas temprana en el sitio de sombe que en el sitio bajo el sol solamente para los huevos colocados durante el inicio del mes de diciembre. La duración de la eclosión de huevos fue mas corta para los huevos puestos tempranamente que en comparación con los huevos puestos mas tarde. La duración del estadio de huevo (calculado de la fecha mediana de oviposición hasta la fecha mediana de la eclosión de huevos) fue negativamente correlacionada con el tiempo cuando los huevos fueron puestos. Estos resultados sugieren que las diferencias en el tiempo de la eclosión de huevos entre los habitares puede ser afectados por el micro hábitat y la fecha de la oviposición.

Insect performance is strongly influenced by the environments in which the insects and their host plants grow. In forests, the environment around a plant may vary both temporally and spatially (Bazzaz 1979). The phenology of dormancy, leaf emergence, and leaf senescence of trees of the upper layer may result in seasonal changes in the quality and quantity of sunlight reaching different regions of the forest floor, e.g., forest edges, gaps, understory, and open areas next to forests (Denslow et al. 1990; Uemura 1994; Gill et al. 1998; Seiwa 1998; Kato & Komiyama 2002). These differences in quality and quantity of sunlight within the forest may result in variable temperature, humidity, food quality, and predation by natural enemies, and may consequently influence the development, growth, survival, and abundance of insects (Rausher 1979; Lowman 1992; Shure & Wilson 1993; Dudt & Shure 1994; Louda & Rodman 1996; Bergman 1999; McDonald et al. 1999).

Host plant phenology, including the timing of budburst and leaf senescence, may be affected by environmental conditions; for example, by exposure to sun or shade (Furuta 1990; Lowman 1992; Seiwa 1999). This is particularly important in the early spring when synchrony between the time of egg hatching and the budburst plays an important role

in the performance and population growth of insects (Dixon 1976; Holliday 1977; Wint 1983; Watt & McFarlane 1991; Hunter 1992; Akimoto & Yamaguchi 1994; Quiring 1994; Lawrence et al. 1997; Van Dongen et al. 1997; Martel & Kause 2002).

The maple aphid, *Periphyllus californiensis* Shinji, dwells on maple trees year-round. In the early spring, stem mothers (fundatrix), the first parthenogenetic generation appearing from fertilized eggs (Miyazaki 1987), hatch from overwintering eggs and give rise to one or more winged or wingless spring generations by parthenogenesis. This aphid feeds on growing buds, leaves, shoots, and the inflorescence in spring. As leaves expand, the soluble nitrogen concentration in the phloem declines, and aestivating dimorphs are produced. In the summer, aestivating dimorphs remain as first instars, mostly on leaves, until autumn when they resume growth and become wingless adults as the food quality improves once again. In spring and autumn, winged females disperse among maple trees (Furuta 1987). In spring and autumn, the performance of the maple aphid is closely attuned to the budburst and leaf senescence phenology of its host trees. In spring, the numbers of stem mothers and their survival rates are higher on early-budding trees than on late-budding trees (Furuta 1987). Therefore, reproduction of stem mothers is mostly observed on early-budding trees, and their winged progeny disperse to late-budding trees where they reproduce in turn (Furuta et al. 1984). In autumn, the population increases first on early-senescing trees, and the winged female progeny of the aestivating dimorphs then disperse to late-senescing trees on which they then reproduce. As a result, oviparae are produced earlier on early-senescing trees than on late-senescing trees (Furuta 1986). The budburst and leaf senescence phenology of the maple tree, *Acer palmatum*, is influenced by the light conditions experienced by the trees (Furuta 1990). Environmental differences in exposure to sun and shade may thus affect development of the egg stage of the maple aphid, and the host tree phenology may also affect the reproductive schedules of the autumnal population and subsequent egg hatching.

In this study, the egg hatching of *P. californiensis* was studied on *Acer amoenum* Carriere saplings in two microhabitats with different light conditions and microclimates, i.e., the understory of a maple stand (a shaded site) and an open area in a nursery (a sunny site) over a 2-year period. Two questions were examined. First, do microclimatic differences between sites cause differences in the timing of egg hatching between microhabitats? Second, does the timing of oviposition have an effect on the timing of egg hatching?

Materials and Methods

The study was conducted from spring 1997 until spring 2000 in the Forest Experimental Station at Tanashi (35°N; 139°E; 60 m elev.), situated in Nishitokyo-shi, Tokyo, Japan. Two study sites, a maple stand understory and an open area in a nursery, were selected in order to observe the phenology of the egg hatching of *P. californiensis* and the budburst of *A. amoenum*. The maple stand was shaded by the trunks and branches of overstory trees in winter and early spring (hereafter called the 'shaded site'). The nursery was in an open field with no shading (hereafter called the 'sunny site'). The two study sites were separated by about 100 m.

Egg Hatching and Budburst in the Field

Potted saplings,15-40 cm high, of *A. amoenum* from the same provenance randomly placed in either the sunny or shaded site from the spring of 1997 were used for observing the budburst phenology. At the sunny site, 28 and 19 saplings were observed, while 25 and 12 saplings were observed at the shaded site in 1999 and 2000, respectively. Budburst (defined as the time when leaves first become visible from opening buds) was monitored every 2-3 days from the beginning of February in both years. The median date of budburst was determined from counts of all buds on all saplings. The cumulative percentage of budbursts was estimated by averaging the accumulated percentage of budbursts across all saplings.

In autumn 1998, only saplings at the shaded site had established natural maple aphid colonies. In order to permit observation of egg hatching at both study sites, fourth instar-adult oviparae and males collected from *Acer* spp. in the field were artificially placed onto saplings at both sites on December 11, 1998.

Eggs laid by oviparae in autumn 1999 were observed in 2000. Adult oviparae were observed on saplings at the sunny and shaded sites at the beginning and the end of December 1999, respectively. In spring 2000, all hatched stem mothers were removed after each observation. Observations were made every other day beginning in February and ending in April in both years.

Unlike other studies that indicated high overwintering mortality of aphid eggs (Leather et al. 1995; Wade & Leather 2002), no obvious mortality of eggs was observed in this study. Since larval syrphids are the primary predators of the maple aphid in spring at the study sites, the eggs of syrphids were regularly removed from the study saplings whenever they were found in order to prevent predation of newly-hatched aphids.

Effect of Microhabitat and Oviposition Period

Oviparae were collected from maple trees in the field during four periods in 1999 on December 1-2, 7-10, 15-18, and 23-27. These oviparae were maintained in the lab on four to eight 15-30-cm-

high saplings of *A. amoenum* growing in the shade. Eggs were collected from these oviparae over short periods in the laboratory to minimize the effects of host plants or environments on the oviparae. On the last day of each period, all oviparae were removed, and the saplings with eggs were transferred to the field where they were placed in either the sunny or shaded site. Egg hatching was then recorded every 2 days during spring 2000, and all hatching stem mothers were removed during each observation.

Data Transformation and Statistical Analysis

Most statistical analyses in this study were performed with SYSTAT (version 8, SPSS, Chicago, IL, USA). The means and variation of the timing of egg hatching were compared between study sites by *t*-test and *F*-test (Elliott 1971), respectively. Patterns of egg hatching were compared by plotting regression lines of logit-transformed proportion of eggs hatched against degree-days within each study site. Differences between slopes and elevations of the regression lines were compared (Zar 1999). Slopes were compared first, and elevations were only analyzed when slopes showed significant differences. Degree-days were calculated by the Sine method (Frazer & Gilbert 1976; Pruess 1983; Raworth 1994) and were accumulated above 4.58°C from 1 February 2000 (Wang & Furuta 2002). Daily minimum and maximum temperatures were obtained from the Forest Experimental Station at Tanashi. Weekly maximum and minimum temperatures at the sunny and shaded sites were recorded by hanging a maximum/minimum thermometer about 40 cm above the ground on the north side of a wooden box from February to the beginning of April 2000. The relationships between these weekly maximum or minimum temperature data within each study site (y) and weekly maximum or minimum temperature data obtained from the Tanashi Experimental Station (x) were calculated by linear regression. Then, the daily temperature data from the Tanashi Experimental Station were applied to the equations to obtain estimated daily maximum and minimum temperatures for each study site.

RESULTS

Egg Hatching and Budburst in the Field

Egg hatching at the shaded site occurred earlier than that at the sunny site in both years (Fig. 1). Egg hatching occurred about 10 and 6 days earlier at the shaded site in 1999 and 2000, respectively (t = 19.339, df = 783, $P < 0.001$; t = 9.408, $df = 823, P < 0.001$), but variation in time of egg hatch between sites was the same in both years (in 1999: $F_{434/349} = 1.107$, $P > 0.05$; in 2000: $F_{38/785} = 1.474$, $P > 0.05$).

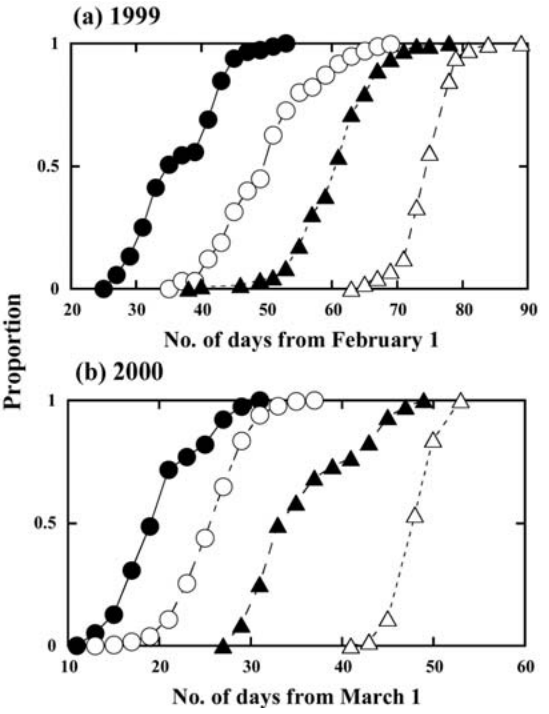

Figure 1. Proportion of eggs hatched (circles) and buds burst (triangles) in the sun (open) and shade (solid) against time in (a) 1999 and (b) 2000.

The median dates of budburst were about 14 and 13 days earlier at the shaded site than at the sunny site in 1999 and 2000, respectively. The degree of synchrony between egg hatching and budburst varied between sites and years. At the shaded site, budburst began when 56% and 97% of the eggs had hatched in 1999 and 2000, respectively. At the sunny site, budburst began when 97% and 100% of the eggs had hatched in 1999 and 2000, respectively. The interval between the date when the first egg hatched and the date of the first budburst at the shaded site was 13 and 16 days in 1999 and 2000, respectively. At the sunny site, the interval was 28 days in both years. The interval between the median dates of egg hatching and budburst at the shaded site was 26 and 16 days in 1999 and 2000, respectively, and 24 and 21 days at the sunny site.

Effect of Microhabitat and Oviposition Period

The timing of egg hatching varied between sites and among oviposition times (by two-way ANOVA: Site, $F_{1/721} = 5.312$, $P < 0.05$; Time, $F_{3/721} = 7.218, P < 0.001$). Between sites within each oviposition period, eggs laid on December 7-10 began to hatch 6 days earlier at the shaded site than at the sunny site. There were no differences between sites for eggs laid in other periods. The median

date of egg hatching was 4 days earlier at the shaded site than at the sunny site for eggs laid on December 1-2 and 15-18 (Table 1). The variation in the timing of egg hatching between sites differed for eggs laid on December 7-10 ($F_{105/110}$ = 1.620, $P < 0.05$). Patterns of egg hatching between sites had significantly different slopes for eggs laid on December 1-2 and 7-10, and similar slopes but significantly different elevations for eggs deposited during the other two periods (Fig. 2, Table 1).

When oviposition periods were compared within sites, eggs laid on December 1-2 began to hatch about 8-14 days later than those laid on December 7-27. The duration of egg hatching (calculated as the number of days from when the first to the last eggs hatched) was shortest for eggs laid on December 1-2 (23-25 days), and longest for eggs laid on December 23-27 (39-41 days). The median duration of the egg stage (calculated as the number of days from the median oviposition date to the median egg hatching date) was negatively correlated with the date of oviposition (correlation coefficient r = -0.982, n = 8, $P < 0.001$). The longest egg stage duration was 109-113 days for those laid on December 1-2, and the shortest was 86 days for those laid on December 23-27. When patterns of egg hatching were compared within each study site, only the eggs laid on December 7-10 and 23-27 hatched at the shaded site revealed the same regression lines, as did eggs laid on December 15-18 and 23-27 hatched at the sunny site (Table 1).

Discussion

Eggs at the understory site hatched a little earlier and tended to require fewer thermal units for egg development than those at the open site. Differences in patterns of egg hatching between sites tended to be larger for eggs laid earlier in December than those laid later. Egg diapause termination can be affected by two thermal features, the length of the lower temperature exposure and the actual temperatures eggs experience (Leather et al. 1995). Therefore, it is possible that greater extremes of temperature in the open site compared with the understory site may have influenced the thermal conditions for egg diapause termination (Tauber & Tauber 1976; Day 1984; Tauber et al. 1986; Fisher et al. 1994; Wang & Furuta 2002), and the speed of egg development during the post-diapause stage (Augspurger & Bartlett 2003), which generated differences in the timing of egg hatching between sites. Furthermore, differences in microclimates between sites might be larger when the deciduous canopy is still closed than they are after overstory trees lose their leaves (Gill et al. 1998; Kato & Komiyama 2002). The last tree shorter than 2 m high to shed its leaves at the shaded site did so by December 21, 1999 (Wang 2002). Therefore, differences between sites may have decreased over time in December and have resulted in larger environmental differences between sites for eggs laid early in December than for those laid later.

Table 1. Time and patterns of egg hatching at the sunny and shaded sites for four specific oviposition periods in December. Patterns of egg hatching were expressed with regression lines plotting logit-transformed proportion eggs hatched against degree-days above 4.58°C from February 1, 2000 and compared by Tukey's test.

Oviposition period	N	Egg hatching		Regression equation	r^2	Between	
		Period	Median date			Sites*	Periods*
Dec 1-2							
Shaded	35	Mar 7-29	Mar 19	y = -10.2 + 0.0662 x	0.954		
Sunny	50	Mar 7-31	Mar 23	y = -9.91 + 0.0501 x	0.976		
Dec 7-10							
Shaded	105	Feb 22-Mar 29	Mar 21	y = -6.03 + 0.0384 x	0.960		dE
Sunny	110	Feb 28-Mar 31	Mar 19	y = -10.0 + 0.0564 x	0.991		
Dec 15-18							
Shaded	118	Feb 22-Mar 31	Mar 15	y = -5.72 + 0.0410 x	0.974	a	dF
Sunny	153	Feb 22-Mar 31	Mar 19	y = -6.96 + 0.0401 x	0.996	a	G
Dec 23-27							
Shaded	94	Feb 22-Mar 31	Mar 19	y = -6.33 + 0.0419 x	0.992	b	EF
Sunny	64	Feb 22-Apr 2	Mar 19	y = -6.03 + 0.0376 x	0.975	b	G

*Test results from all regression lines by Tukey's test. Only those between sites within periods and among periods within sites are shown. Slopes and elevations of values with the same capital letters do not differ. Slopes of values with the same small letters do not differ, but the elevations differ. Slopes of values without the same letters differ.

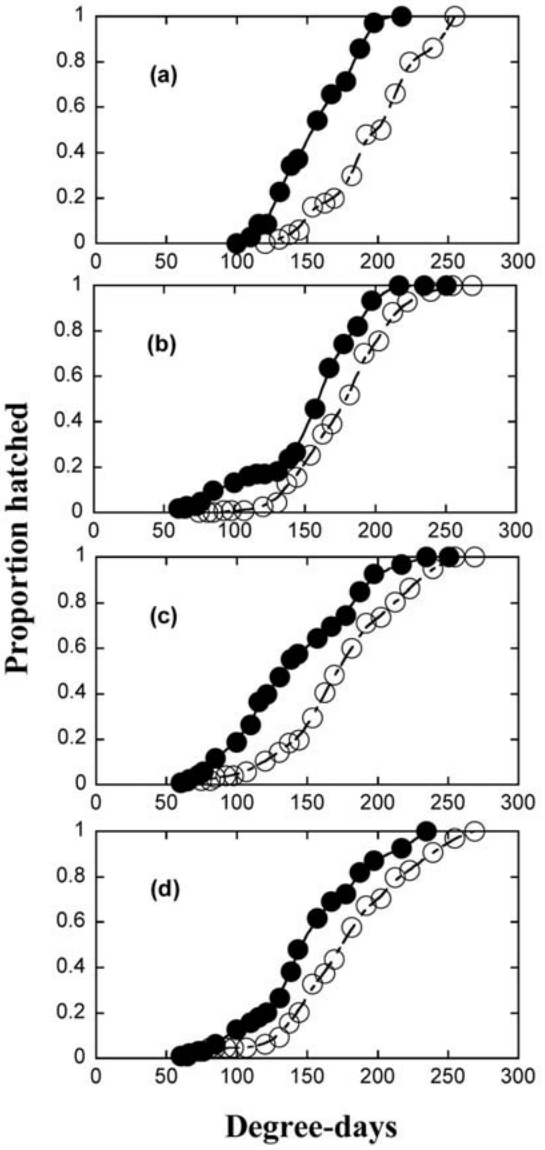

Figure 2. Proportion of eggs hatched in the sun (open) and shade (solid) for eggs laid during (a) December 1-2, (b) 7-10, (c) 15-18, and (d) 23-27 against degree-days accumulated above 4.58°C from February 1.

The duration of the egg stage was longer for eggs laid earlier in December than for those laid later. In a laboratory study (Wang & Furuta 2002), eggs of *P. californiensis* deposited earlier in December also exhibited delayed hatching compared to those deposited later. The period from December 7-18, 1999, in this study seemed to be the critical oviposition period for the timing of egg hatching. In the Tokyo region, the temperature gradually decreases in December, and day length is shortest between December 16 and 26 (Japan Weather Association 1997). Because higher temperatures and changing day length have been implicated in the production of eggs with more-intensive diapause, i.e., entering a longer diapause, for some insects (Tauber et al. 1986; Masaki 1996), it is possible that oviparae might be stimulated by the higher temperatures and longer day lengths in early December thus producing eggs with more-intensive diapause than those produced later in the winter. In addition to the direct effects of microhabitats and oviposition times on eggs examined in this study, determining other potential factors which might have affected egg conditions through oviparae, e.g., genetic variation (Komatsu & Akimoto 1995), maternal effects (Mousseau 1991; Bradford & Roff 1993; Cherrill 2000; Roff & Bradford 2000; Denlinger 2002), and host plant quality (Hunter & McNeil 1997), may require further detailed investigations.

The duration of egg hatching was shorter and its onset was about 1-2 weeks later for eggs laid on December 1-2 than for those laid later. Fewer eggs were used in the experiment on December 1-2 as oviparae could only be found on early-senescing trees in small numbers. Therefore, eggs laid on December 1-2 may reflect the hatching pattern for those laid on early-senescing trees. After December 1-2, oviparae became increasingly abundant on both early- and late-senescing trees and were collected on both kinds of trees. Eggs laid during the period December 7-27 may represent a combination of both late- and early-hatching eggs, and this would be consistent with a longer period of egg hatching for this cohort.

Acer palmatum growing in the shade tends to break buds earlier and enter senescence later than those in full sun (Furuta 1990). Saplings of *Acer saccharum* are known to break buds earlier and enter senescence later in the understory than in gaps (Augspurger et al. 2003), and the results of the present study are consistent in this regard. Changes in a plant's phenology in different light environments may result from understory trees avoiding canopy shade in order to maximize net carbon gain (Uemura 1994). Because aphids are sap-sucking insects, the soluble nitrogen in the sap is critical for their growth (Dixon 1998). The maple aphid can only feed and grow on developing buds until leaf expansion is complete. They produce normal winged or wingless offspring when food quality is high, and aestivating dimorphs when food quality declines (Hashimoto & Furuta 1988). In spring, most stem mothers are found on early-budding trees, and their progeny, which develop into winged adults, disperse to late-budding trees and reproduce there (Furuta 1987). When food quality becomes poor, only dimorphs are produced. These aestivating first instars will aestivate on leaves for several months until leaf senescence begins in autumn. Autumnal populations build up earlier on early-senesc-

ing trees than on late-senescing trees, and winged individuals maturing on early-senescing trees can also colonize and reproduce on late-senescing trees. This results in the earlier appearance of oviparae on early-senescing trees than on late-senescing trees. Thus the entire life cycle of the maple aphid is driven by the host plant phenology, including the production of oviparae and eggs.

Egg hatching of the maple aphid occurs earlier than the budburst. This phenomenon has also been observed in the gall-forming aphid *Hormaphis hamamelidis* which hatches in advance of the budburst (Rehill & Schultz 2002). In the early spring, stem mothers of the maple aphid can stay on the bud scales before bud growth begins, but they will not molt to second instars until the buds start to swell (Furuta 1990). Because stem mothers can survive starvation conditions for a time (Wang 2002), hatching earlier than bud swelling may permit immediate initiation of growth when suitable food becomes available, although it also incurs the cost of a longer period of exposure to natural enemies (Price et al. 1980). In addition, early hatching increases the chance that multiple generations can be completed on both early-budding and other late-budding trees. Thus the highest potential fitness will be obtained by stem mothers hatching early on early-budding trees.

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GENETIC VARIATION WITHIN AND BETWEEN STRAINS OF THE FALL ARMYWORM, *SPODOPTERA FRUGIPERDA* (LEPIDOPTERA: NOCTUIDAE)

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ABSTRACT

Limited information exists on molecular genetic variation and distribution of the corn and rice strains of the fall armyworm, *Spodoptera frugiperda* (J.E. Smith). This study was conducted to investigate the genetic structure of *S. frugiperda* across a part of its range in the United States. A 608-base-pair portion of the mitochondrial cytochrome oxidase I and II genes was sequenced from 71 individuals resulting in three corn and four rice strain haplotypes. Genetic divergence between the two strains ranged from 0.66 to 0.99%. A 562-base-pair region of the nuclear ITS-1 gene was also amplified and sequenced from 17 individuals representing both corn and rice strains. No variation was detected in any of the samples for the ITS-1 region. Analysis of molecular variance was conducted on the resulting mtDNA haplotypes from the Arkansas and Florida populations and as a hierarchical analysis between populations in the two states. Results indicate a significant overall Φ_{ST} for all populations with the hierarchical analysis revealing that this significant Φ_{ST} is due to structuring of the populations between states. The observed genetic structure is possibly due to the distribution of fall armyworm strains.

Key Words: COI, COII, ITS-1, DNA sequence, genetic variation, population genetics, *Spodoptera frugiperda*

RESUMEN

Existe información limitada sobre la variación genética molecular y distribución de las razas del cogollero, *Spodoptera frugiperda* (J.E. Smith) de maíz y de arroz. Este studio fue realizado para investigar la estructura genética de *S. frugiperda* a través de una parte de su rango de distribución en los Estados Unidos. Una porción de los 608 pares de bases de los genes I y II del citocromo—c-oxidasa mitocondrial fueron secuenciados de 71 individuos resultando en tres haplotipos de la raza de cogollero en el maíz y cuatro haplotipos de la raza de cogollero en el arroz. La divergencia genética entre las dos razas de cogollero fue de 0.66 a 0.99%. Una región de 562 pares de bases del gene nuclear ITS-1 también fue amplificada y secuenciada de 17 individuos representando ambas razas de maíz y de arroz. Ningún variación fue detectada en las muestras para la región ITS-1. Un análisis de variancia fue realizado usando los haplotipos resultantes de ADNmt de las poblaciones de Arkansas y de Florida, al igual que un análisis de jerarquía entre las poblaciones de los dos estados. Los resultados indican una Φ_{ST} total significativa para todas las poblaciones con el anális de jeraquía revelando que esta Φ_{ST} significativa es debido a la estructura de las poblaciones entre los dos estados. La estructura genética observada posiblemente es debido a la distribución de las razas de cogollero.

The fall armyworm, *Spodoptera frugiperda* (J.E. Smith), is a major pest on corn, sorghum, and bermudagrass in the southeastern United States (Knipling 1980; Pashley 1986; Sparks 1979). The preferred host plants of the fall armyworm came under new scrutiny in 1986 when Pashley proposed that the fall armyworm consists of two morphologically undistinguishable strains, a corn strain that prefers corn, cotton, and sorghum, and a rice strain that prefers rice and bermudagrass (Pashley 1986, 1988a). The range of *S. frugiperda* is known to cover most of the Western hemisphere, and the range of each strain, however, has been examined from Louisiana down through Central America and in the Caribbean to Brazil (Pashley et al. 1985; Pashley 1986, 1988b).

Despite the possible benefits that population genetic analysis of the fall armyworm may provide towards understanding dispersal, monitoring the spread of insecticide resistance, and the implementation of area-wide control programs, relatively little research in this area has been conducted. A survey of 22 allozyme loci by Pashley et al. (1985) indicated significant heterogeneity between populations at five of 11 polymorphic loci, due in large part to the distinctness of a single Puerto Rican population collected from rice. The phylogenetic relationships between the two

strains were further examined with three of these polymorphic allozymes (Hbdh, PepF, and Est3; Pashley 1988b). The majority of the genetic studies have focused on differentiating the rice and corn strains with polymerase chain reaction restriction fragment length polymorphism (PCR-RFLP), strain specific PCR, RFLP, amplified fragment length polymorphism (AFLP) and allozyme markers (Meagher & Gallo-Meagher 2003; Levy et al. 2002; Nagoshi & Meagher 2003; McMichael & Prowell 1999; Pashley et al. 1985; Lu et al. 1992; Adamczyk 1993; Lu & Adang 1996; Pashley 1989). A genetic variation study by Lu et al. (1992) involving RFLP of a random genomic library from six populations (five of which were lab colonies) from Louisiana, Mississippi, and Georgia revealed high levels of genetic variation within and among populations. However, no population genetic analysis was conducted in that study, which focused on finding diagnostic markers for the corn and rice strains.

Mitochondrial-DNA (mtDNA) analysis is generally assumed to be more powerful than allozyme analysis for revealing population structure, and has been used for numerous population genetic studies (Avise 1994). The cytochrome oxidase I (COI) and cytochrome oxidase II (COII) regions of the mtDNA genome have proved useful for measuring genetic variation in numerous insect taxa (Szalanski & Owens 2003; Austin et al. 2002; Taylor et al. 1997; Brower & Jeansonne 2004). Comparison of mtDNA variation with a nuclear genetic variation can provide insight into current versus historical gene flow in a species. For example, high levels of mtDNA variation combined with a lack of nuclear DNA variation may indicate unidirectional mating between strains.

We investigated the extent of genetic variation within and between races of fall armyworm using DNA sequences of a portion of the mitochondrial COI and COII genes, and the nuclear rRNA first internal transcribed spacer (ITS-1) region.

Materials and Methods

Larval fall armyworm samples were collected from sorghum and cotton in Raymond, MS and Colfax, LA, respectively (Table 1). Additional larval samples were obtained from southern Florida and Altheimer, Arkansas, and larval and pupal samples from lab colonies maintained at the University of Mississippi and the University of Florida also were obtained. Larval species identification was confirmed with morphological keys of Peterson (1962), and samples were designated as corn or rice strain based on the host from which they were collected (Table 1). Fall armyworm adults were collected with pheromone traps through summer and fall of 2001 to 2003 from three locations in Arkansas: Tillar, Foreman, and Fayetteville (Table 1). The traps at Tillar were located on the border of experimental research plots of different field crops (cotton, corn, soybean, and sorghum). The adjacent landscape was predominantly cotton with limited acreages of soybean, rice, and corn. A large commercial field of coastal bermudagrass was located within ¼ mile of the traps. The location at Foreman was on a grain farm and the predominant crops were corn, soybean, peanuts, and sorghum. Some limited areas of commercial pasture were near the sample areas. The location at Fayetteville was on an agricultural research farm located in an urban/suburban area. Diverse crops and grasslands were located nearby. Adult fall armyworm identification was confirmed by comparing DNA sequences to larval fall armyworm and other noctuid DNA sequences (unpublished data).

DNA was extracted from individual moths, larvae, and pupae with the Puregene DNA isolation

Table 1. Sampling locations and frequency of fall armyworm corn "C" and rice "R" haplotypes.

Location	Strain*	C1	C2	C3	R1	R2	R3	R4	*n*
Fayetteville, Washington Co., AR	—	11	2			3			16
Tillar, Drew Co., AR	—	6		1		3			10
Foreman, Little River Co., AR	—	7				3	1		11
Altheimer, Jefferson Co., AR	R					4			4
Starkville, Oktibbeha Co., MS	C	2							2
Raymond, Hinds Co., MS	C	2							2
Colfax, Grant Parish, LA	C	2							2
Gainesville, Alachua Co., FL	C	2							2
Ona, Hardee Co., FL	R				4	3			7
Miami-Dade Co., FL	R					6		1	7
Collier Co., FL	R					5			5
Broward Co., FL	R					2	1		3
n		32	2	1	4	29	1	1	71

*Strain designation based on host from which larvae were collected.

kit D-5000A (Gentra, Minneapolis, MN). Voucher specimens are maintained at the Arthropod Museum, Department of Entomology, University of Arkansas, Fayetteville, AR. DNA vouchers, preserved on filter paper according to Owens & Szalanski (2005), are maintained at the Insect Genetics Laboratory, Department of Entomology, University of Arkansas, Fayetteville, AR.

PCR reactions were conducted with 1 μl of the extracted DNA with New England Biolabs (Ipswich, MA) *Taq* DNA polymerase with thermopol buffer. Approximately 608 bp of a mtDNA region containing the COI, tRNA leucine, and COII genes was amplified with the primers C1-J-2797 (5'-CCTCGACGTTATTCAGATTACC-3') (Simon et al. 1994) and C2-N-3400 (5'-TCAATATCATTGATGACCAAT-3') (Taylor et al. 1997). The mtDNA marker was amplified with a thermal cycler profile consisting of 35 cycles of 94°C for 45 s, 46°C for 45 s and 72°C for 45 s according to Szalanski et al. (2000). A 562-bp section of the nuclear 3' portion of 18S rDNA, all of ITS-1, and the 5' portion of 5.8S were amplified with the primers rDNA2 (5'-TTGATTACGTCCCTGCCCTTT-3') (Vrain et al. 1992) and rDNA 1.58S (5'-GCCACCTAGTGAGCCGAGCA-3') (Cherry et al. 1997) with a thermal cycler profile consisting of 40 cycles of 94°C for 45 s, 53°C for 1 min and 72°C for 1 min as described by Szalanski & Owens (2003). Amplified DNA from individual moths was purified and concentrated with minicolumns according to the manufacturer's instructions (Wizard PCRpreps, Promega). Samples were sent to The University of Arkansas Medical School DNA Sequencing Facility (Little Rock, AR) for direct sequencing in both directions.

Consensus sequences were derived from both of DNA sequences from an individual with Bioedit 5.09 (Hall 1999) to verify nucleotide polymorphisms, and sequences were aligned by CLUSTAL W (Thompson et al. 1994) for both mtDNA and nDNA sequences. Mitochondrial DNA haplotypes were aligned by MacClade v4 (Sinauer Associates, Sunderland, MA). GenBank accession numbers were AY714298 to AY714304 for the different fall armyworm haplotypes. Genealogical relationships among mtDNA haplotypes were constructed with TCS (Clement et al. 2000) and the method described by Templeton et al. (1992). The distance matrix option of PAUP* 4.0b10 (Swofford 2001) was used to calculate genetic distances according to the Kimura 2-parameter model of sequence evolution (Kimura 1980). Tests for population differentiation were conducted by AMOVA as implemented in Arlequin v. 2.0 (Schneider et al. 2000). An analog of FST, Φ_{ST}, was calculated from the haplotypes frequencies and Tajima and Nei (1984) genetic distances (Excoffier et al. 1992). Initially, AMOVA was used to test mtDNA genetic differentiation among all Arkansas and Florida populations sampled (Φ_{ST}). Subsequently, a hierarchical AMOVA was conducted in which populations were grouped into states to determine differentiation between states (Φ_{CT}) and among populations within states (Φ_{ST}). Pairwise comparisons, calculated independently for all Arkansas and Florida population pairs of Φ_{ST} also were calculated. Permutations of the data set were used to determine statistical significance of the pairwise comparisons ($P < 0.05$).

Results

Mitochondrial DNA sequencing of 71 fall armyworm samples revealed an amplicon size of 608 bp. Nucleotide positions 1 to 222 were COI, 223 to 289 tRNA-leu, and 290 to 608 COII. The average base frequencies were A = 0.36, C = 0.13, G = 0.09, and T = 0.42. Corn haplotype C1 was the most common haplotype for the corn strain and occurred in all of the sampled locations where the corn strain occurred (Table 1). The other two corn strain haplotypes were found only in Arkansas. Rice strain haplotype R2 was the most common haplotype and occurred in every location where the rice strain was found. Rice strains R1 and R4 were found only in Florida, while strain R3 was found in both Arkansas and Florida.

Nine nucleotide sites were variable among the observed three corn and four rice strain haplotypes (Table 2). Three variable nucleotide sites were located in the COI gene and the remainder were located in the COII gene. Tajima-Nei distances (Tajima & Nei 1984) among the fall armyworm haplotypes ranged from 0.164 to 0.329% for the corn strain, 0.164 to 0.329% for the rice strain, and 0.658 to 0.987% between strains. Fig. 1 shows the 95% parsimony network for the seven haplotypes (Posada & Crandall 2001). Missing haplotypes probably represent sampling gaps.

DNA sequencing of the nuclear ITS-1 region from 17 FAW samples (Table 3) revealed an amplicon size of 562 base pairs. No sequence variation was detected in any of the 17 individuals and the base frequencies were A = 0.23, C = 0.24, G = 0.26, and T = 0.27.

AMOVA detected a significant overall Φ_{ST} (0.493, $P < 0.001$) when comparing mtDNA genetic variation among populations (Table 4). The amount of variation was almost equal within versus among populations (within 50.74%, among 49.26%). Hierarchical AMOVA conducted between Arkansas and Florida populations detected a significant Φ_{CT} (0.387, $P < 0.005$) between the two states (Table 4). The comparison among groups accounted for 38.70% of the observed variation.

Discussion

This genetic investigation of the fall armyworm mtDNA revealed significant levels of genetic differentiation among populations both

TABLE 2. GENETIC VARIATION AT NINE NUCLEOTIDE SITES AMONG FALL ARMYWORM HAPLOTYPES.

Haplotype	55	76	79	361	367	403	421	511	529
Corn 1	A	C	A	T	T	A	C	T	C
Corn 2	T	.	.	.	.	.	.	.	.
Corn 3	.	.	C	.	.	.	.	.	.
Rice 1	.	T	.	C	C	G	.	.	A
Rice 2	.	T	.	C	C	.	.	.	A
Rice 3	.	T	.	C	C	.	T	.	A
Rice 4	.	T	.	C	C	.	.	C	A

within and between the two fall armyworm strains. This research also represents the first attempt to determine the geographical distribution of fall armyworm haplotypes from mtDNA sequence data as well as determining the extent of genetic variation within each strain. A haplotype or allele is defined by one unique form of the gene and differs from any other gene by at least one nucleotide. Haplotype diversity or gene diversity quantifies the number of haplotypes in relation to their relative frequency to each other, and haplotype diversity is described as the probability that two sequences randomly selected from a population are different (Nei 1987).

Four haplotypes were observed for the rice strain and three haplotypes were found for the corn strain, although it is likely more haplotypes may be discovered for each strain. Observed genetic variation between strains was approximately 0.66%. Estimated time of divergence between corn and rice strain is approximately 287,000 years based on a molecular clock rate of 2.3% divergence per million years (Brower 1994). Populations of nearly all species, social or otherwise, exhibit at least some degree of genetic differentiation among geographic locales (Ehrlich & Raven 1969). This observation becomes more difficult to accurately discern when dealing with a migratory species such as the fall armyworm; however, more studies such as this one could help determine the migratory paths of the insect.

One of the purposes of the research presented herein was to estimate the baseline genetic variation which occurs both within and between fall armyworm strains. As with other animal populations, additional genetic structure normally is to be expected over increasing spatial scales, where populations can show additional differentiation due to spatial habitat structure, isolation by distance, or other factors (Avise 1994). There may be temporal differences in the occurrence of the rice and corn. Temporal data, obtained by sampling the same area throughout a season and over a period of years, also may provide insight into the specific migratory patterns of the fall armyworm.

Comparing mtDNA sequences with nuclear markers can provide evidence of inter-strain mating within a species. The lack of variation in the nuclear rDNA ITS-1 region combined with previously conducted laboratory-based mating studies (Pashley & Martin 1987; Whitford et al. 1988; Nagoshi & Meagher 2003) suggests that inter-strain mating does occur in the field. However, the lack of genetic variation in the rDNA ITS-1 region

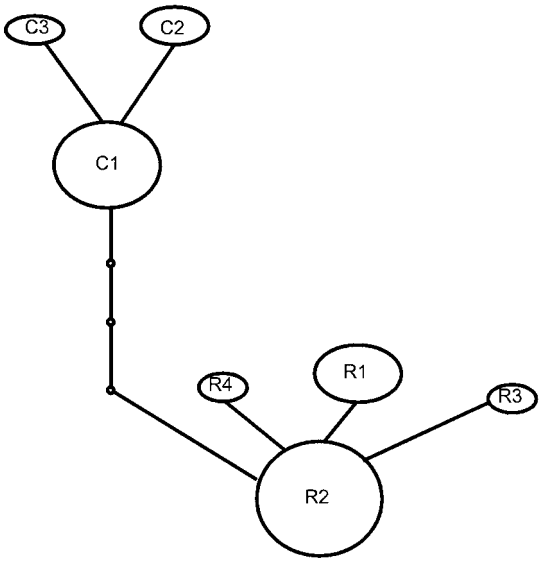

Fig 1. Genealogical relationships among 7 haplotypes of fall armyworm estimated by TCS (Clement et al. 2000). The size of the ovals corresponds to haplotype frequency, and a unit branch represents one mutation. Small ovals indicate haplotypes that were not observed.

TABLE 3. SAMPLING LOCATIONS OF FALL ARMYWORM WITH NUCLEAR RDNA ITS-1 MARKER.

County	State	mtDNA haplotype (*n*)
Washington	AR	C1(3), C2(1), R2(1)
Little River	AR	C1(3)
Drew	AR	C1(5)
Jefferson	AR	R2(2)
Collier	FL	R2(1)
Broward	FL	R3(1)

TABLE 4. ESTIMATES OF GENETIC DIFFERENTIATION CALCULATED AMONG ARKANSAS AND FLORIDA POPULATIONS AS ONE HIERARCHICAL GROUP (ONE GROUP) AND WITH AN ADDITIONAL HIERARCHICAL GROUP BETWEEN STATES (TWO GROUPS). IN BOTH, THE AMOUNT OF VARIATION OCCURRING AMONG CATEGORIES AND THE ESTIMATE OF GENETIC DIFFERENTIATION IS PROVIDED. AN ASTERISK DENOTES STATISTICAL SIGNIFICANCE AT $\alpha = 0.05$.

Hierarchy	Categories	%Variation	Φ estimate
One Group	Among Populations	49.26	$\Phi_{ST} = 0.493$*
	Within Populations	50.74	
Two Groups	Among Groups	38.70	$\Phi_{CT} = 0.387$*
	Among Populations Within Groups	19.45	$\Phi_{ST} = 0.582$*
	Within Populations	41.85	

must be approached with caution, because this marker has no power to detect gene flow and this invariant region may be ancestral to strain subdivision. Prowell et al. (2004) also reported a lack of variation in the ITS-1 region of the fall armyworm, but it was cited as unpublished data.

Based on this study, there appears to be sufficient genetic variation both within and between populations to substantiate a more comprehensive population genetics study on this species, and we would recommend also that temporal data be taken into consideration.

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MIAMI BLUE BUTTERFLY LARVAE (LEPIDOPTERA: LYCAENIDAE) AND ANTS (HYMEOPTERA: FORMICIDAE): NEW INFORMATION ON THE SYMBIONTS OF AN ENDANGERED TAXON

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ABSTRACT

Historical, anecdotal records of the state-endangered Miami blue butterfly, *Cyclargus thomasi bethunebakeri* (Comstock & Huntington) (Lepidoptera), have mentioned larval associations with the Florida carpenter ant, *Camponotus* sp. Recent population studies confirm that *C. t. bethunebakeri* larvae associate with *Camponotus floridanus* (Buckley) as well as another member of the genus, *Camponotus planatus* (Roger). Additionally, caterpillars have been observed tended by *Crematogaster ashmeadi* (Emery), *Forelius pruinosus* (Roger), and *Tapinoma melanocephalum* (Fab.). Field surveys of remaining Miami blue habitat and recent butterfly reintroduction sites reveal other potential ant associates, *Paratrechina longicornis* (Latreille) and *Paratrechina bourbonica* (Forel), and a host of possible predaceous ant species. The corresponding conservation implications are discussed. Detailed information is also presented about larval ant-associated organs and their mediation of this facultative symbiosis.

Key Words: Ant organs, butterfly-ant relationship, facultative symbiosis

RESUMEN

Registros históricos y anecdóticos de la mariposa en peligro de extinción Miami blue, *Cyclargus thomasi bethunebakeri* (Comstock y Huntington) (Lepidóptera) mencionan la asociación de sus larvas con la hormiga carpintera, *Camponotus* sp. Estudios recientes poblacionales confirman que las larvas de *C. t. bethunebakeri* están asociadas con *Camponotus floridanus* (Buckley), como también con otro miembro del género, *Camponotus planatus* (Roger). Adicionalmente, se observaron orugas atendidas por *Crematogaster ashmeadi* (Emery), *Forelius pruinosus* (Roger), y *Tapinoma melanocephalum* (Fabricius). Análisis de campo del hábitat remanente de la mariposa Miami blue y de localidades de reintroducciones recientes, revelaron asociaciones potenciales con otras especies de hormigas, *Paratrechina longicornis* (Latreille) y *Paratrechina bourbonica* (Forel), y un hospedero de posibles especies de hormigas depredadoras. Las implicaciones de conservación son discutidas en este artículo. Así mismo, se presenta información detallada sobre los órganos involucrados en la asociación larva-hormiga y su intervención en esta simbiosis facultativa.

Translation provided by the authors.

INTRODUCTION

The Miami blue, *Cyclargus thomasi bethunebakeri* (Comstock & Huntington) (Lycaenidae: Polyommatinae), represents one of Florida's rarest endemic butterflies and is currently listed as state-endangered. Once commonly found in tropical coastal hammocks, beachside scrub, and tropical pine rocklands from the southern Florida mainland south through the Florida Keys to Key West and the Dry Tortugas, the species' overall distribution and numerical abundance has been reduced to a single remaining metapopulation within the boundaries of Bahia Honda State Park in the Lower Keys (Klots 1964; Kimball 1965; Lenczewski 1980; Minno & Emmel 1993; Ruffin & Glassberg 2000; Calhoun et al. 2002). Developing larvae of *C. t. bethunebakeri* have been shown to be tended by ants in the genus *Camponotus* but the extent of the relationship remains poorly understood (Minno & Emmel 1993). Recent population studies of the butterfly at Bahia Honda State Park and additional reintroduction sites within Everglades National Park confirm a continued association.

Over 75 percent of lycaenid larvae with known life histories associate with ants (Pierce et al. 2002). Such myrmecophilous relationships may be mutualistic to varying degrees or even para-

sitic whereby larvae are predatory in ant nests (Pierce & Mead 1981; Fiedler & Maschwitz 1988; New 1993). The resulting communication between larvae and ants is mediated by a complex array of tactile, chemical, and often audible signals (DeVries 1990). Specifically, larvae possess highly specialized organs that can extrude alarm, reward, or appeasement chemicals. In response, tending ants often protect the surrounding larvae from a variety of natural predators and parasitoids, and thus can potentially provide a benefit for survival (Thomas 1980; Webster & Nielson 1984; Pierce & Easteal 1986; Savignano 1994). Cushman & Murphy (1993) suggest that ant associations also may play an important role in the persistence of lycaenid populations. They additionally propose that species with a dependence on ants, whether facultative or obligatory, display an increased sensitivity to environmental change, and thus are more susceptible to endangerment than species that lack ant associations. Here, we identify additional ant associates and potential predatory ant species and discuss the corresponding implications for the conservation and recovery of the Miami Blue butterfly, a critically imperiled butterfly.

Materials and Methods

Field surveys of ant species were conducted at Bahia Honda State Park and the Flamingo Campground, Rowdy Bend Trail, and Bear Lake Road sites in southern portions of Everglades National Park during daylight hours on 24-27 May, 2004 and 31 July-2 August, 2004. These areas contain low numbers of *Cyclargus thomasi bethunebakeri*, either as part of a remaining natural metapopulation or as reintroduced individuals. Hand-collecting and baiting were used to survey ants on and around patches of the butterfly's larval host, *Caesalpinia bonduc* (L.) Roxb. (Fabaceae). Sugar baits consisting of index cards with approximately 10 g of crushed pecan cookie were placed along transects at the base of *C. bonduc* plants. Baits were left in the field for one hour, at which time all cards were collected in Ziploc-style plastic bags. Additionally, when *C. t. bethunebakeri* larvae were found in association with ants, 1-2 ant specimens were collected from the tended larvae.

Finally, to provide additional detail on the structure of the larval ant organs, three *C. t. bethunebakeri* larvae from a captive colony maintained at the University of Florida were preserved and used for SEM and Auto-Montage photographic analysis. Larvae were placed in near boiling water for 60 seconds, transferred to 25% ethanol for two hours, 50% ethanol for another two hours, and stored in 75% ethanol before being photographed. No additional preparation or gold coating was done to prepare specimens.

Results

Eighteen ant species were collected in Everglades National Park and Bahia Honda State Park (Table 1). Of these, *Camponotus floridanus*, *Camponotus planatus*, *Crematogaster ashmeadi*, *Forelius pruinosus*, and *Tapinoma melanocephalum* were confirmed to tend larvae of *Cyclargus thomasi bethunebakeri*. Late instars were always found in association with ants but early instars, prepupae, and pupae were frequently found without ants present. *Camponotus floridanus* tended larvae for the majority of the observations and all other ants were encountered 1-2 times, with no two species tending larvae simultaneously. Two ants typically tended a larva at a time, with the exception of *Crematogaster ashmeadi* which often tended in higher numbers (Fig. 1).

We name two additional species, *Paratrechina longicornis* and *Paratrechina bourbonica*, as potential ant associates. The former species was found in proximity to *C. t. bethunebakeri* larvae and appeared to tend them although encounters were brief. The latter species was observed tending larvae of another lycaenid, *Strymon martialis* (Herrich-Schäffer), on *Caesalpinia bonduc* at Bahia Honda State Park. No predation by these ants was observed.

Details of the ant organs of *C. t. bethunebakeri* are shown in Fig. 2. Second through fifth instars possess a dorsal nectary organ (=honey gland) with associated perforated cupola organs on abdominal segment A7 and a pair of eversible tentacular organs on abdominal segment A8. Abdominal segments A7 and A8 are fused dorsally. Tentacular organs were observed to evert independently in the field when stimulated by attendant ants, and liquid droplets from the dorsal nectary organ were actively imbibed by all species of ants. *Camponotus floridanus* became excited and agitated, evidenced by increased body and antennal movements, when the tentacular organs were everted.

Discussion

This study documents *Camponotus floridanus* to be the primary ant species attending Miami blue larvae. *Camponotus floridanus* is a native ant species primarily active at night throughout Florida; they are commonly found foraging on *C. bonduc* and tending *C. t. bethunebakeri* larvae in both the Everglades and Bahia Honda locations. *Camponotus planatus* is a diurnal species, but is not commonly encountered in association with larvae, having never been found tending larvae in the Everglades and only once in Bahia Honda. It is possible that in higher densities *C. planatus* may more regularly tend larvae and could potentially be important at protecting larvae during the day. Buckley & Gullan (1991) have shown that more aggressive ants provide better

TABLE 1. ANTS OF EVERGLADES NATIONAL PARK AND BAHIA HONDA STATE PARK COLLECTED IN PROXIMITY TO THE ENDANGERED MIAMI BLUE BUTTERFLY *CYCLARGUS THOMASI BETHUNEBAKERI* WITH INFORMATION ON TROPHIC INTERACTIONS.

	Park Location		
	Everglades	Bahia Honda	Ant Status
Subfamily Pseudomyrmicinae			
Pseudomyrmex elongatus (Mayr)	1	2	P
Pseudomyrmex gracilis (Fab.)	1	-	P
Pseudomyrmex simplex (Smith)	-	1	P
Subfamily Myrmicinae			
Crematogaster ashmeadi (Emery)	-	1, 2	S
Monomorium floricola (Jerdon)	1	2	u
Pheidole dentata Mayr	1	2	u
Pheidole floridana Emery	1	1	u
Solenopsis invicta Buren	-	1, 2	P
Solenopsis geminata (Fab.)	1	1, 2	u
Tetramorium simillimum (F. Smith)	1	-	u
Wasmannia auropunctata (Roger)	1	1, 2	P
Subfamily Dolichoderinae			
Forelius pruinosus (Roger)	1	1, 2	S
Tapinoma melanocephalum (Fab.)	-	1	S
Subfamily Formicinae			
Brachymyrmex obscurior Forel	1	1, 2	u
Camponotus floridanus (Buckley)	1, 3	1, 2	S
Camponotus planatus (Roger)	1	1	S
Paratrechina bourbonica (Forel)	-	1	pS
Paratrechina longicornis (Latreille)	1	1, 2	pS

Collectors/Authors: 1 = present study; 2 = Deyrup et al. (1988), 3 = Ferster and Prusak (1994).
S = confirmed symbiont of *C. thomasi bethunebakeri* (present study); pS = potential symbiont; u = unknown; P = potential predator (noted as a predaceous ant in included literature).

protection for soft scales and mealybugs, and as a corollary the large and potentially aggressive *Camponotus* species may prove effective in deterring predators and parasitoids (Axén 2000).

Crematogaster ashmeadi were observed tending individual larvae in Bahia Honda but have not yet been observed with larvae in the Everglades. While not commonly found tending larvae, interactions involving *C. ashmeadi* were characterized by a minimum of five individuals. This behavior demonstrates the quality of their trailing and recruitment signals. Other *Crematogaster* species have been found worldwide to tend lycaenid larvae and this genus seems predisposed to lycaenid symbioses (Atsatt 1981; Fiedler 1991; Pierce et al. 2002; Saarinen 2005). These ants are equipped with a flexible abdomen and attached sting; despite their small size they are potentially capable of defending larvae from other ants or harmful invertebrates.

Both *Forelius pruinosus* and *Tapinoma melanocephalum* may be opportunistically imbibing food rewards from *C. t. bethunebakeri* larvae. Field observations suggest that their behavior offers little or no protection for the larvae they tend;

Fig. 1. *Crematogaster ashmeadi* ants tending a late instar *Cyclargus thomasi bethunebakeri* larva. Several other *C. ashmeadi* ants were present but not visible in this photo. Photo by Jaret Daniels.

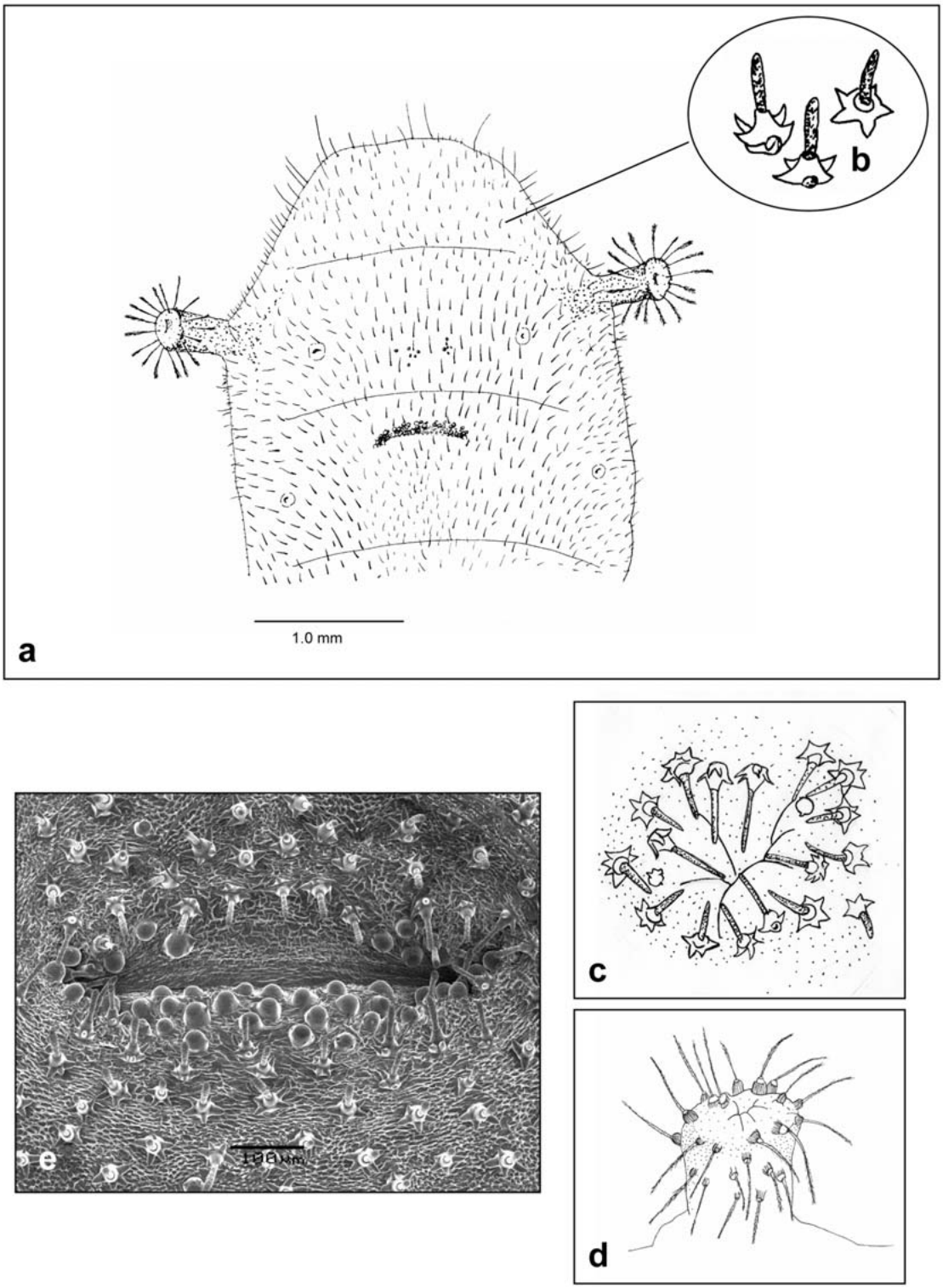

Fig. 2. Details of *Cyclargus thomasi bethunebakeri* fifth instar. a, dorso-posterior abdominal segments (A7-A8) showing ant organs; b, detail of cuticular setae; c, tentacular nectary organ inverted; d, tentacular nectary organ everted (cuticular setae omitted); e, dorsal nectary organ bordered by perforated cupolas. Figures by Emily Saarinen.

however merely their presence may deter predators. Both *Paratrechina longicornis* and *P. bourbonica*, along with *T. melanocephalum*, have been referred to as "tramp ants" (Passera 1994). While such species may not provide demonstrative protection for larvae, at the very least they tolerate nearby larvae and coincidentally tend instars feeding on *C. bonduc* flowers and buds adjacent to where the ants are also gathering nectar.

The facultative ant associations of *C. t. bethunebakeri* encompass four genera (five including *Paratrechina*) and three subfamilies; Formicinae, Myrmicinae, and Dolichoderinae. These lycaenid larvae may secrete "non-specific" ant semiochemicals as attractants to various ant species, as proposed by Henning (1983). These chemicals, primarily from the tentacular organs and potentially from the perforated cupola organs, may serve to alarm, excite, or appease ants. Further study into the chemical secretions of all ant organs may clarify the "intentions" of the larvae in their emissions. Further comparisons of each ant species' alarm and attractant pheromones with those isolated from lycaenid volatiles may further elucidate ant-larval relationships, including if certain ants are chemically targeted and if others are simply opportunistic tenders.

No interactions between other identified ant species and *C. t. bethunebakeri* larvae were observed. Several of these ants, however, may be predating larvae at other times. All three *Pseudomyrmex* species may be predators, possibly excepting *P. simplex* (Smith) due to its small size. Miami blue larvae are always found in proximity to abundant colonies of *Camponotus floridanus* and further field observations, especially at night when *C. floridanus* are most active, need to be carried out to assess interactions within the ant mosaic of symbionts and predators.

This study also shows the persistence of *Wasmannia auropunctata* (Roger) on Bahia Honda State Park (first recognized there by Deyrup et al. 1988). This invasive tramp ant is native to the New World tropics and its presence in the Florida Keys may be a cause for concern. *W. auropunctata*, also known as the little fire ant is an opportunistic feeder that forages day and night and bears a painful sting. Both *W. auropunctata* and the red imported fire ant, *Solenopsis invicta* Buren, have been implicated in the displacement of endemic species, resulting in a loss of biodiversity (Meier 1994; Wojcik 1994). Neither ant has been found near *C. t. bethunebakeri* in the Everglades, nor have they been observed harvesting immatures or predating adults in Bahia Honda. *Solenopsis invicta* mound density is perhaps not high enough to impact the *C. t. bethunebakeri* metapopulation on Bahia Honda because they do not appear as large or extensive in area as those found in more disturbed habitats (personal observation). Further field work will need to examine predation rates by ants and the specific impact that these invasive ants may have on endemic butterfly species, especially species of special concern.

Ant attendance may be critical to the long-term survival of lycaenid taxa by impacting larval development time, larval weight gain, and other developmental responses (Robbins 1991; Wagner 1993). The presence of an ant guard has led to larger, more fecund adults in the related butterfly *Hemiargus isola* (Reakirt) (Wagner 1993). However in the Australian species *Jalmenus evagoras* (Donovan), ant-tended larvae pupate at a smaller size, pupate for a shorter duration, and develop into smaller adults (Pierce et al. 1987). In an assessment of potential ant partners, it was shown that *Tapinoma sessile* (Say) is a "neutral partner" for the widely distributed North American lycaenid *Glaucopsyche lygdamus* (Doubleday), providing no significant cost or benefit (Fraser et al. 2001). Researchers of the critically imperiled European lycaenid butterfly *Maculinea rebeli* (Hirschke) have repeatedly emphasized "the importance of identifying local host ant species prior to further management conservation strategies in order to avoid failure of management programs or even damage to populations on the edge of extinction" (Steiner et al. 2003). Ant attendance, obligate or facultative, is not trivial; it can have profound effects on the length of time individuals spend in vulnerable immature stages as well as the resulting fecundity of adults. Both symbiotic ant partnerships and the negative impacts of predaceous ants should be addressed in management plans for the conservation of endangered lycaenid taxa.

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NEW RECORDS FOR THE CICADA FAUNA FROM FOUR CENTRAL AMERICAN COUNTRIES (HEMIPTERA: CICADOIDEA: CICADIDAE)

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ABSTRACT

Analysis of museum specimens has added to the cicada fauna of Belize, El Salvador, Guatemala, and Honduras. Information on the cicada fauna reported in the literature as well as the first records of cicada species to the fauna are reported here to provide a more accurate understanding of cicada diversity in each country and the region. The new records represent an increase of 75, 14, 110, and 320%, respectively, to the cicada faunal diversity of each country.

Key Words: cicadas, biodiversity, Central America

RESUMEN

Un estudio de los especimenes de museos han incrementado la fauna de las chicharras (Hemiptera: Cicadidae) de Belize, El Salvador, Guatemala y Honduras. Información sobre la fauna de las chicharras reportadas en la literature, los nuevos registros de las especies mencionadas en este articulo estan reportados para proveer un entendimiento mas preciso de la diversidad de las chicharras en cada país de la región. Estos nuevos registros representan un aumento de 75, 14, 110, y 320%, respectivamente, en la diversidad de la fauna de chicharras en estos paises.

The Central American cicada fauna has received little study since Distant's *Biologia Centrali-Americana* (Distant 1881, 1883, 1900, 1905). Davis (1919, 1928, 1936, 1941, 1944) described new cicada genera and species, primarily from specimens he received from Mexico. Since that time, most work on Central American cicadas has focused on the ecology of Costa Rican (Young 1972, 1976, 1980, 1981) and Panamanian (Wolda 1984, 1993; Wolda & Ramos 1992) cicadas with limited work being done on the Mexican fauna (Moore 1962, 1996; Sueur 2000, 2002; Sanborn 2006). The lack of knowledge was illustrated in the paper by Sanborn (2001), who identified the first cicadas to be reported from El Salvador. The taxonomic position of some of the Central American species has been altered (Boulard & Martinelli 1996; Moulds 2003) and the process of describing new species (Sueur 2000; Sanborn et al. 2005) has begun but there are still many species to be described (Sanborn unpublished).

I have come across multiple species in various museum collections that have not been described as being part of the cicada fauna in several Central American countries as published in the Cicadoidea bibliographies (Metcalf 1963a, b, c; Duffels & van der Laan 1985) or more recent literature. I have now identified specimens from several collections and individuals that represent additions to the cicada fauna of Belize, El Salvador, Guatemala, and Honduras. These new additions to the cicada fauna of the region are identified along with a listing of previously identified species from the various countries to provide a current view of the cicada fauna for the region.

MATERIALS AND METHODS

Specimens for this study were found among the undetermined material in the collections of the Florida State Collection of Arthropods (FSCA), the Smithsonian Institution, United States National Museum (USNM), San Diego Natural History Museum (SDMC), Bohart Museum of Entomology at the University of California at Davis (UCDC), Carnegie Museum of Natural History (CMNH), University of Mississippi Insect Collection (UMIC), William R. Enns Entomological Museum, University of Missouri (UMRM), University of Connecticut (UCMS), University of Georgia (UGCA) and three individuals who donated their specimens to the author. Original specimens are housed in the collections above with vouchers of most species and the specimens donated to the author in the author's collection. The number of species previously attributed to each country was determined from the cicada bibliographies (Metcalf 1963a, b, c; Duffels & van der Laan 1985) and the more recent literature. Original references can be located in these materials.

RESULTS

The regional cicada fauna for Belize, El Salvador, Guatemala, and Honduras is summarized here. Species identified as new to a country in-

clude available collection information. Bibliographic information is provided for species that have been described previously from a country.

There are currently four species that have been collected in Belize, one of which is a recently described new species (Sanborn et al. 2005). Three species are added to the cicada fauna with this report. The cicada fauna of El Salvador was unknown until I reported on representatives of seven species collected in the country (Sanborn 2001). One additional species was found in the collection of the USNM. There are currently ten species attributed to Guatemala. Eleven additional species are added to the fauna in this report. There are currently five species reported to inhabit Honduras. One of these is a recently described species (Sanborn et al. 2005). Sixteen new species records are added in this report.

Family Cicadidae

Subfamily Tibiceninae Atkinson, 1886

Tribe Zammarini Distant, 1905

Odopoea signoreti Stål, 1864. Specimens in the UMIC collected at Honduras, Olancho, La Union, Parque Nacional La Muralia, 15.07°N 86.45°W, 17-V-1996. The species is described from México (Metcalf 1963a).

Miranha imbellis (Walker, 1858). Specimens in the FSCA collected at Honduras, Cortés, Parque Nacional Cusuco, 15°29'47'N 88°12'43"W, 1600 m, 1-VII-2000. It has been reported previously from Guatemala and Central America (Metcalf 1963a).

Zammara smaragdina Walker, 1850. Specimens in the FSCA were collected in Guatemala, Petén at the Tikal Ruins. Specimens in the SDMC were collected at Honduras, Atlántida, El Pino, Morrañas Arriba, 12-VIII-1979 and specimens in the UGCA were collected at Honduras, Olancho, Dulce Mombre de Culmi, Montaña de Malacate, 26-VII-2001 and 11-VI-2003. The species is described from Central America (Metcalf 1963a).

Zammara smaragdula Walker, 1850. Specimens from Guatemala, Petén, Morajan, 4.8 km East of Poptun, IV-V-1993 were given to the author by Br. Leon Cook. The species is described from Central and South America (Metcalf 1963a).

Zammara tympanum (Fabricius, 1803). A specimen collected in Belize, Cayo District, Maya Mountain Lodge, 19-VII-1993 was given to the author by Vince Golia. The FSCA has specimens from Guatemala, Izabal, Puerto Barrios Cerro, San Gil, 1,000 m, 13-IV-1992. The UGCA contains specimens from Honduras, Cortéz Merendón, 1500 m, adjacent to Parque Nacional De Cusuco, N15°30'12", W88°11'54", collected 19-V-2002 and 24-VII-2001. The species is described from South and Central America (Metcalf 1963a; Duffels & van der Laan 1985).

Tribe Tibicenini Distant, 1889

Diceroprocta belizensis (Distant, 1910). Specimens in the UMRM are from Guatemala, Escuintla, Nueva Concepcion, 30-VII-1985. Specimens have been reported previously from Belize, Honduras (Metcalf 1963a) and El Salvador (Sanborn 2001).

Diceroprocta bicosta (Walker, 1850). Specimens have been reported from Honduras (Metcalf 1963a) and El Salvador (Sanborn 2001).

Diceroprocta bulgara (Distant, 1906). A female in the UCMS was collected in Guatemala, Sacatepequez, Cerro Alux, 2,000 m, X-2002. The species is described from México (Metcalf 1963a).

Diceroprocta pusilla Davis, 1942. The FSCA has specimens collected at Guatemala, Guatemala, 11-V-1991; Honduras, Atlántida, RVS Cuero y Salado, Salado Barra, 15°46'N 89°59'W, 2 m, 1-VIII-2000; Olancho, 1.1 km North of El Cerro, 750 m, 15°08'48"N 85°33'19"W, 19-IV-1999; and Honduras, Cortes, 9.3 km NNW Cofradia, 800 m, 15°29'14"N 88°11'22"W, 16-VI-1999. The species is described from México (Metcalf 1963a).

Diceroprocta ruatana (Walker, 1850). Specimens have been reported from Honduras (Metcalf 1963a).

Cacama maura (Distant, 1881). The FSCA has specimens from Honduras, Olancho, Culuco, Aguan Valley, 29-III-1978. The species is described from México (Metcalf 1963a).

Tribe Fidicinini Distant, 1905

Proarna insignis Distant, 1881. The FSCA has specimens from Guatemala, Izabal, La Graciosa, 15-IV-1995. The FSCA also has specimens collected at Honduras, El Paraiso, 7 km North of Oropoli, 30-IV-1993 and Atlántida, RVS Cuero y Salado, Salado Barra, 15°46'N 89°59'W, 2-5 m, 22-IV to 1-VIII-2000. There is a specimen from Honduras, El Paraiso, Yuscaran, 1-VI-2003 in the UGCA. The species has been reported in Central America (Metcalf 1963a).

Proarna olivieri Metcalf, 1963. The UCDC contains specimens collected at Guatemala, Retalhuleu, Retalhuleu, 18-23-VI-1986 and Retalhuleu, Retalhuleu, El Asintal, 6-V-1989. The UCMS contains a male from Guatemala, Chimaltenango, Pochula Fca El Rosario, 15-IV-2003. The species has been reported in Central America (Metcalf 1963a).

Proarna sallaei Stål, 1864. The UGCA has a specimen collected at Honduras, Atlántida, ~20 km SW La Ceiba, base of Pico Bonito, 16-VII-2001. The species is described from México (Metcalf 1963a).

Pacarina championi (Distant, 1881). The FSCA has specimens from the Belize, Toledo District, Punta Gorda, 5-8-VI-1990. Specimens in the CMNH were collected at Honduras, Rio Grande.

The species has been reported from Guatemala and Central America (Metcalf 1963a).

Pacarina puella Davis, 1923. The species has been reported from Guatemala and Central America (Metcalf 1963a).

Pacarina schumanni Distant, 1905. Specimens collected in Belize, Cayo District, Maya Mountain Lodge, 19 and 20-VII-1993 were given to the author by Vince Golia. Additional specimens collected by Charles Bartlett were collected in the Belize, Cayo District, Teakettle Bank, Pooks Hill, 17°09.257'N 88°51.094'W, 294 ft., 8-VII-2003 and given to the author. Specimens in the SDMC were collected at Belize, Chaa Creek, 18-21 August 1987. Specimens in the FSCA were collected at Honduras, La Paz, San Martin, 1-V-1988 and at Honduras, Colon, Trujillo, 22-VII-1968. Specimens have been reported from El Salvador (Sanborn 2001).

Sub-tribe Fidicinina Boulard & Martinelli, 1996

Fidicina cachla Distant, 1899. Specimens from Honduras, El Paraiso, 8.3 km SE Capire, 675 m, 13°58'54"N 85°49'25"W, 16-IV-1999 are in the FSCA. The species is described from Costa Rica (Metcalf 1963a).

Fidicinoides determinata (Walker, 1858). The FSCA has specimens from Guatemala, Guatemala, 1-V-1994. There are also specimens in the FSCA from Honduras, Yoro, Parque Nacional Pico Bonito, El Portillo, 640 m, 15°26'27"N 87°08'09"W, 11-III-2000; and Honduras, Atlántida, Parque Nacional Pico Bonito, El Manchon, 350 m, 15°29'18"N 87°07'39"W, 18-III-2001. The species has been reported from El Salvador (Sanborn 2001).

Fidicinoides pronoe (Walker, 1850). The FSCA has specimens collected in Honduras, Olancho, 14 km east of La Colonia, 610 m, 28-IV-1993; and Honduras, Lempira, Montana de Puca, 14°42'00"N 88°34'07"W, 1150 m, 28-VI-2000. Specimens have been reported previously from El Salvador (Sanborn 2001) and Guatemala (Metcalf 1963a).

Sub-tribe Guyalnina Boulard & Martinelli, 1996

Dorisiana amoena (Distant, 1899). Specimens from Guatemala, Petén, Morajan, 4.8 km East of Poptun, IV-V-1993 were given to the author by Br. Leon Cook. The species is described from Costa Rica (Metcalf 1963a).

Majeorona truncata Goding, 1925. A specimen from Honduras, Atlántida, PN Pico Bonito, Estacion CURLA, 17-VII-2001 is in the UGCA. The species is described from Ecuador (Metcalf 1963a).

Tribe Hyantinii Distant, 1905

Quesada gigas (Olivier, 1790). It has been reported from Central America, Belize, Guatemala, Honduras (Metcalf 1963a) and El Salvador (Sanborn 2001).

Tribe Cicadini Oshanin, 1907

Neocicada centramericana Sanborn, 2005. The species is reported from Belize, Guatemala and Honduras (Sanborn et al. 2005).

Cicada pennata (Distant, 1881). The species is described from Guatemala (Metcalf 1963b). The taxonomic position of the species remains unclear based on the description of a single female specimen.

Subfamily Tibicininae Distant, 1906

Tribe Dazini Distant, 1905

Daza montezuma (Walker, 1850). Specimens in the FSCA from Guatemala, Petén, Cam. Yaxhá-Nakum, 180-300 m, 30-VI-1992. The species is described from México (Metcalf 1963a).

Tribe Carinetini Distant, 1905

Carineta trivittata Walker, 1858. The FCSA has specimens from Honduras, Cortés, Cofradia, Cusuco, 26-VIII-1994. The species has been reported from Guatemala and Central America (Metcalf 1963c).

Herrera ancilla (Stål, 1864). The FSCA has specimens collected in Honduras, El Paraiso, 5.3 km N Cifuentes, N 15°08'04" W 85°35'36", 13-14-VI-1999, Honduras, EAP, 30 km ESE of Tegus, 23-V-1983 and EAP 35 km Este Teg., 20-VII-1983. The species has been reported from Central America, Belize, Guatemala (Metcalf 1963c) and El Salvador (Sanborn 2001).

Tribe Taphurini Distant, 1905

Chrysolasia guatemalena (Distant, 1883). The species is described from Guatemala (Metcalf 1963c).

Dorachosa explicata Distant, 1892. A single specimen collected at El Salvador, San Salvador, San Salvador, 3-6-VI-1958 is in the USNM. The species is described from Panama (Metcalf 1963c).

Discussion

This work has added significant numbers of representatives to the cicada fauna of the northern Central American countries (Fig. 1). However, there are probably many additional cicada species present in each country. The distribution of a species may bypass an individual country while being reported from border countries. It may be that insufficient collecting has occurred to produce representatives of these species in some countries, e.g., neighboring Guatemala, Honduras, and Nicaragua have been reported to have 24 species and 13 genera not reported from El Salva-

Fig. 1. Summary listing of first species records for the Central American countries of this study.

dor here and in Sanborn (2001). Continued museum study and field work will no doubt result in the identification of new species and additions to the cicada fauna of each country.

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VERTICAL POSITION OF TRAPS INFLUENCES CAPTURES OF EASTERN CHERRY FRUIT FLY (DIPTERA: TEPHRITIDAE)

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The eastern cherry fruit fly, *Rhagoletis cingulata* (Loew), is an important late-season pest of cherries in the eastern and Midwestern United States (Bush 1966). Adults emerge from overwintering puparia in mid-June, mate on the host fruit, and lay eggs into cherries (Pettit & Tolles 1930; Boller & Prokopy 1976; Smith 1984).

Michigan produces approximately 75% of the total U.S. tart cherries, *Prunus cerasus* L., and 12% of the U.S. sweet cherries, *P. avium* (L.) L. (Anon. 2004). Zero tolerance standards for fly larvae in fruit require sensitive fly monitoring systems early in the growing season as part of integrated pest management (IPM) programs to prevent fruit infestation. To monitor *R. cingulata* flies, Pherocon AM boards are placed approximately 2.1 m (depending on the tree size) from the ground within the tree canopy. The yellow traps are typically baited with an ammonia and protein hydrolysate lure (Liburd et al. 2001), providing both visual and olfactory cues to attract flies. The first insecticide is applied after a single fly is captured on a monitoring trap.

Steady progress has been made in developing effective trapping systems for some important *Rhagoletis* pests of temperate fruit crops. Trap placement has been optimized for monitoring the apple maggot fly, *R. pomonella* (Walsh), (Reissig 1975; Drummond et al. 1984) and the blueberry maggot, *R. mendax* Curran (Liburd et al. 2000; Teixeira & Polavarapu 2001). The optimal position for traps to monitor *R. pomonella* is approximately 2.1 m above the ground (depending on the tree size) within the apple tree canopy (Reissig 1975; Drummond et al. 1984) and 0.25-0.5 m from fruit, while traps for *R. mendax* are most effective when placed within the top of highbush blueberry plants, *Vaccinium corymbosum* L., when the bushes are 1.5 to 2.0 m high (Liburd et al. 2000; Teixeira & Polavarapu 2001). To date, the optimal positioning of traps for monitoring *R. cingulata* has not been reported; however, based on studies of related fruit fly species, we hypothesized that the height of trap placement within the cherry tree canopy would affect captures of *R. cingulata* on monitoring traps.

In 2002 and 2003, trap heights were compared in mature, unmanaged tart cherry orchards located in southwestern Michigan (Van Buren Co.) with high populations of *R. cingulata*. The orchards used in these experiments contained unsprayed, mature trees approximately 4.6 m in height, and planted in a 2.4-m within-row by 6.1-m between-row spacing. This spacing allowed sunlight to reach the entire tree, rather than the topmost portion only. In addition, branches from adjacent trees did not overlap.

The effect of trap height on captures of *R. cingulata* was determined by placing unbaited Pherocon AM traps (Trécé, Inc., Adair, OK) at three positions midway between the tree trunk and outermost foliage of cherry trees. All traps were placed on the southwest side of trees. Three treatments were evaluated that included placing traps as follows: (1) below the tree canopy (approximately 1.2 m above ground), (2) at the standard trap height (approximately 2.1 m), or (3) in the top portion of the tree canopy (approximately 4.6 m). In order to obtain the highest trap position, traps hung at 4.6 m were suspended from a PVC pipe (1.4 m length and 6 mm diam.) affixed to a tree limb such that the traps were within the top portion of the cherry tree foliage midway between the trunk and the outermost foliage. Trees were selected randomly and a single trap was placed at one of the three positions in each tree. Treatments were arranged with a distance of at least 20 m between trees and 30 m between blocks. Foliage surrounding all traps was removed in a 0.5 m radius (Reissig 1975). Five replicates of each treatment were arranged in a randomized complete block design. Flies were counted and removed from traps weekly for six weeks in both years (17 June-30 July 2002 and 16 June-29 July 2003). To minimize position effects, all treatments were rotated one position clockwise after each weekly inspection.

Total fly captures on each trap across the season in both years were subjected to analysis of variance (ANOVA). To normalize the data, square root-transformation $(x + 0.5)^{1/2}$ was performed prior to analysis. Fisher's Least Significant Difference test (LSD, SAS Institute 2000) was used to separate mean differences among treatments (significance level $\alpha = 0.05$).

In 2002, captures of *R. cingulata* were significantly affected by trap location ($F = 79.2$; $df = 2,8$; $P < 0.05$), with more *R. cingulata* flies caught at 4.6 m within canopies of cherry trees than on traps placed at 2.1 m (standard trap height) or 1.2 m (Fig. 1A). Overall, more than three times the number of flies were captured on traps placed at 4.6 m compared with traps hung at lower positions. In 2003, captures of *R. cingulata* flies were significantly affected by trap location ($F = 27.0$; $df = 2,8$; $P < 0.05$). Significantly more flies were caught on traps hung at 4.6 m compared with traps placed at a 2.1 m or 1.2 m height (Fig. 1B).

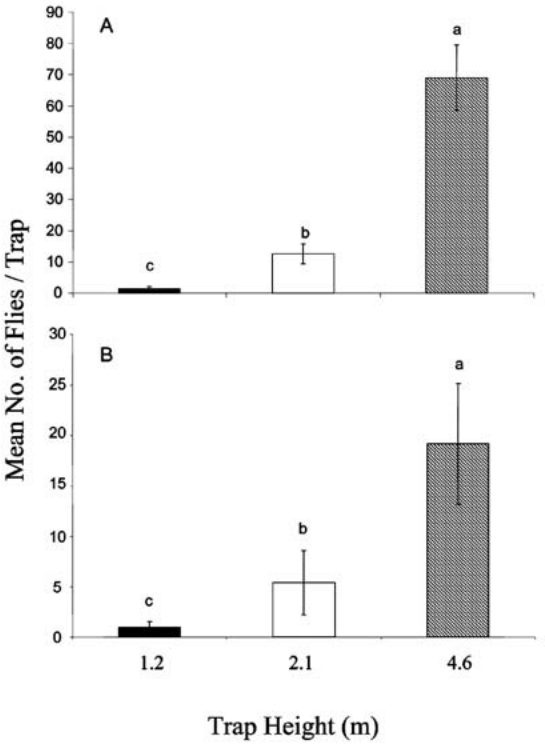

Fig. 1. Number of adult *R. cingulata* captured (± SEM) per season on Pherocon AM boards placed at low (1.2 m), standard (2.1 m), and high (4.6 m) positions within cherry trees. The experiment was conducted in 2002 (A) and 2003 (B). Means with the same letter within years are not significantly different (Fisher's LSD Test, $P < 0.05$). Untransformed means are shown.

Traps in the highest canopy position caught more than three times as many flies as those hung in either of the two lower canopy positions. During both years, the mean number of flies captured in the first week on traps at the high canopy position was greater than the 2.1- and 1.2-m canopy positions (respectively, in 2002: 49.2 ± 3.4, 9.8 ± 1.3, 1.0 ± 0.28; and 2003: 10.2 ± 2.4, 2.4 ± 0.9, 0.0).

Over two growing seasons, more *R. cingulata* were captured on traps placed at the highest position than on those hung at 2.1 m or 1.2 m. Similar results were obtained with *R. mendax* captures within blueberry bushes, where traps placed in the upper third of bushes captured the greatest number of flies (Liburd et al. 2000). In contrast, more *R. pomonella* were captured on Pherocon AM traps placed at 2.1 m within the canopy of apple trees than on traps at 1.2 or 3.0 m (Reissig 1975; Pelz et al. unpublished). Observations of adult *R. indifferens* revealed that the majority of flies were present within three meters of the ground (Frick et al. 1954). Differences in the distribution of fruit fly species within their host tree have also been reported for several tropical fruit flies in the genus *Anastrepha* (Sivinski et al. 2004). Within their respective host trees, *A. alveata* Stone are more abundant in the lower canopy of trees, while *A. striata* Schiner are more abundant in the upper canopy.

Our results suggest that *R. cingulata* activity is greatest in the uppermost portion of the host tree canopy; thus, traps placed higher in the tree may be more visible to *R. cingulata* flies that are active in the upper canopy compared with those placed lower in the tree canopy. Direct observations of *R. cingulata* within cherry trees are necessary to determine whether the distribution of flies is greatest in the upper canopy and whether that distribution changes throughout the day. In addition, assessment of infestation rates at different levels may also be valuable in determining whether peak fly oviposition activity coincides with fly population distribution, as found for *R. indifferens* (Frick et al. 1954) and several *Anastrepha* spp. (Sivinski et al. 1999, 2004). In their study, Frick et al. (1954) found that infestation of sweet cherries by *R. indifferens* was greater in the lower canopy (less than two meters) compared with infestation high in the tree canopy (between two and nine meters).

Finally, the sensitivity and accuracy of monitoring for *R. cingulata* may be improved through trap placement in a location where flies are most abundant; however, because standard trapping methods utilize ammonium acetate lures, further work must be done to determine whether these lures will affect fly captures on traps at different heights.

Summary

In 2002 and 2003, we compared the effect of three trap heights on captures of *R. cingulata* in Michigan cherry orchards. Overall, significantly more flies were captured on unbaited Pherocon AM traps hung at 4.6 m in the canopy of cherry trees than on traps hung at 2.1 m or at a low position of 1.2 m, suggesting that *R. cingulata* is more abundant in the upper portion of the host tree canopy.

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CALLING BEHAVIOR OF *ZAMAGIRIA DIXOLOPHELLA* (LEPIDOPTERA: PYRALIDAE)

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The sapodilla bud borer, *Zamagiria dixolophella* Dyar, has been reported attacking the sapodilla *Manilkara zapota* van Royen in Mexico (Iruegas et al. 2002). The larvae feed on the tender young shoots and fruits. Current control of this species is based upon the use of insecticides; however, chemical control of this pest is difficult due to its cryptic nature. Mating disruption may be an alternative for controlling it. Although in *Z. dixolophella* the pheromone has not been identified yet, it would be worthwhile to understand the influence of different factors in the release of pheromone to obtain a complete picture of the factors governing the biology of the female sex pheromone system. Production and release of the sex pheromone in many moths is influenced by several biotic and abiotic factors (Landolt & Phillips 1997; Rafaeli 2002). In this study, we investigated the possible effect of host plant and the photoperiod on the calling behavior of *Z. dixolophella* under laboratory conditions as a first step to identify the sex pheromone.

Larvae of *Z. dixolophella* were collected in *M. zapota* orchards "El Nayar" (14°49'36"N and 92°20'52"W at 44 masl) and "Cazanares" (14°44'40"N and 92°24'20"W at 20 masl), both located between Tapachula City and Puerto Madero, Chiapas, Mexico. Larvae were held in 3-L clear plastic cylindrical containers (23 cm height × 14 cm diameter), and allowed to feed upon their host plant (tender young shoots) in controlled conditions at 25 ± 5°C and 65 ± 5% R H with a reversed photoperiod of 16: 8 h (L: D) (unless otherwise specified). Pupae obtained were placed in Petri dishes inside plastic cages (30 × 30 cm) and observed constantly one or two days before emergence. Most females emerged during the photophase, and only these were used in the observations. The experiments started during the first complete scotophase after emergence. Females were observed every 10 min throughout their first six scotophases with a red light lamp. The percentage of females calling daily, the daily onset of calling time (time after lights off), and duration of calling of each female were recorded.

The possible influence of host plant in the calling behavior was investigated in two groups of newly emerged virgin females. In the first group, 20 females were individually placed in cylindrical containers (23 cm height × 14 cm diameter). A fresh, tender young host plant shoot with leaves and flowers inserted in a plastic vial with cotton soaked in water was placed in each container. The host plant was changed daily after each scotophase. In the second group, 20 females were placed as described above but without the presence of host plant. The opening of the containers was covered with gauze to permit circulation of air. A drop of natural honey was placed daily on gauze to ensure that females had food *ad libitum*. The observations were made at 25 ± 5°C, 65 ± 5% relative humidity and at 16L: 8 D photoperiod regimen.

The effect of photoperiod on the calling behavior was examined under two different photoperiod regimes: 16L: 8D and 13L: 11: D. In both cases, larvae were collected in the field and once they have reached the pupal stage, pupae were sexed, and the female pupae were preconditioned under the experimental photoperiod at which they were to be observed. Upon emergence females were isolated, placed in individual containers with host plants at 25 ± 5°C and 65 ± 5% relative humidity. Twenty females were tested under each photoperiodic regime.

The percentages of calling females were analyzed by χ^2 test. The data for the daily onset of calling time and duration of calling were analyzed by one-way repeated measures analysis of variance (ANOVA), with age as repeated measure. Means were separated by least significant difference (LSD) at a significance level of 0.05.

Most of the females called from their first scotophase independently of the presence or absence of host plant. The mean daily onset of calling time was not affected by the presence or absence of the host plant, but it differed significantly with age. The interaction between the presence of host plant × age was not significant. Also, the presence of host plant did not affect the length of the calling period, but this parameter was influenced by female age. The interaction between the presence of host plant × age was not significant. In contrast to our results, several studies have shown that the presence of the host plant or its volatile chemicals stimulate the production and releasing of the sex pheromone in several moth species (Hendrikse & Vos-Bünnemeyer 1987; Raina 1988; Raina et al. 1992, 1997; Pittendrigh & Pivnick 1993). Virgin females of *Helicoverpa zea* (formerly

Heliothis) (Boddie) (Raina et al. 1992) and *Heliothis phloxiphaga* G. and R. (Raina 1988) synthesized and released pheromone only in presence of their host plants. However *H. zea* females reared in laboratory for many generations did not require the host plant for the production and release the pheromone (Raina 1988). In presence of its host plant, females of *Plutella xylostella* (L.) began calling at a younger age and they spent more time calling (Pittendrigh & Pivnick 1993).

The percentage of calling females was similar in the two photoperiods evaluated. The mean daily onset time of calling was significantly different under the photoperiods tested, but this parameter was not affected by female age. The interaction between age × photoperiod was significant. In overall, females maintained at 16L: 8D began to call earlier than females held at 13L: 11D, except in the fifth scotophase (Fig. 1a). The length of the calling period differed significantly between the photoperiods evaluated and this parameter was influenced by female age. Also, the interaction between age × photoperiod was significant. Females held at 16L: 8D called longer than females maintained at 13L: 11D (Fig. 1b). Our results are in agreement with the suggestion of Haynes and Birch (1984), who proposed that photoperiod would have a major influence on the calling behavior of multivoltine species such as *Z. dixolophella* because these species are exposed to different photoperiod conditions at different times of the year.

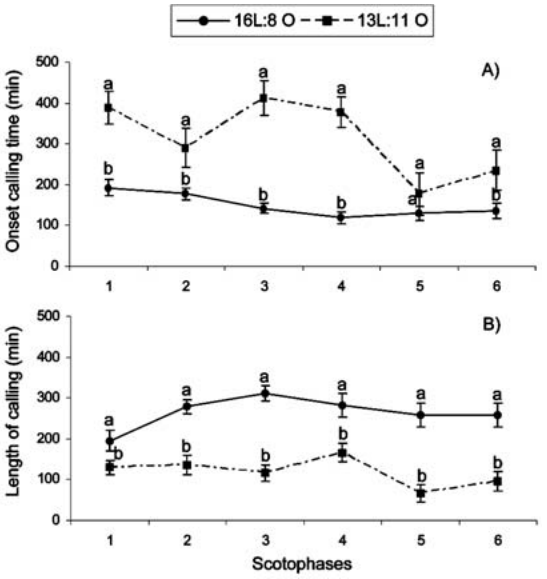

Fig. 1. Calling behavior response of *Z. dixolophella* at two different photoperiods under laboratory conditions (values are means ± SE). (A) Mean (± SE) onset time of calling. (B) Mean (± SE) time spent calling. Different letters indicate significance at $P < 0.05$.

In conclusion, this study shows that the calling behavior of *Z. dixolophella* is influenced by the photoperiod, but not by the presence of host plant. This information will be useful during the collection and identification of sex pheromone.

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Summary

The influence of host plant and photoperiod on calling behavior of the moth *Zamagiria dixolophella*, a sapodilla pest in Mexico was investigated under laboratory conditions. Most of the females called from their first scotophase independently of the presence or absence of host plant. Also, the host plant did not influence the mean onset time of calling and the mean time spent calling. There was an effect of photoperiod on the mean onset time of calling and the mean time spent calling of *Z. dixolophella*.

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DEVELOPMENTAL TIME, REPRODUCTION, AND FEEDING OF TWO SUBSPECIES OF *COLEOMEGILLA MACULATA* (COLEOPTERA: COCCINELLIDAE) IN THE LABORATORY

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Coccinellids (lady beetles, lady bugs or ladybird beetles) have been used in biological control programs because of their ability to prey on economically important pests such as aphids (Hagen & Van den Bosch 1968; Hagen 1974; Frazer 1988; Rondon et al. 2004), whiteflies (Hoelmer et al. 1994) and mites (Chazeau 1985; Rondon et al. 2004) on maize, *Zea mays* L. (Kieckhefer & Elliot 1990), alfalfa, *Medicago sativa* L. (Giles et al. 1994), and potato, *Solanum tuberosum* L. (Groden et al. 1990; Hilbeck & Kennedy 1996). Lady beetles are probably the most visible and well known beneficial predatory insects with over 450 species found in North America (Gordon 1985). *Coleomegilla maculata* DeGeer (Coleoptera: Coccinellidae), the pink spotted lady beetle, is a new world species distributed from southern Canada, U.S. (east of the Rocky Mountains), and Central and South America (Timberlake 1943; Wright & Laing 1982; Gordon 1985; Munyaneza & Obrycki 1998). Three subspecies of *C. maculata* have been described based on morphological characters such as spot patterns, color, body size, genitalia, and geographical distribution (Gordon 1985). According to Gordon (1985) these subspecies are *C. m. fuscilabris* (Mulsant), *C. m. lengi* Timberlake and *C. m. strenua* (Casey). *Coleomegilla m. fuscilabris* is found in the southeastern U.S., including Florida, while *C. m. lengi* is found from Ontario, Canada, through northwestern Georgia. *Coleomegilla m. lengi* has not been reported in Florida (Peck & Thomas 1998). The criteria to determine subspecies based only on morphological and geographical distribution has been challenged several times and even by Darwin (1964). The assertion that "biology should overrule taxonomy and that the term subspecies should be referred to as species rather than subspecies" (anonymous) is open to discussion. Nevertheless, geographic distribution has been defining in allocation of species (Odum 1950); however, the final determination of genotypic characteristics should be considered as definitive in insect identification. There has not been a determination of the actual distribution of subspecies since Gordon (1985). To our knowledge, no further surveys have been made to update the records.

In Florida, there has been an increasing interest from the biological control industry to introduce *C. m. lengi* (non-native), which is thought to have a greater reproductive capability, a highly attractive biological characteristic desired by producers of beneficials, than *C. m. fuscilabris* (native) (Griffin & Yeargan 2002). However, concerns regarding the possibility of cross genetic contamination between *C. m. fuscilabris* and *C. m. lengi* prevented the introduction (Peres 2000). Studies by Peres & Hoy (2002) indicated that there was a reproductive near incompatibility between the subspecies during the first and second generations (F1, F2); conversely, Krafsur & Obrycki (2000) indicated that high levels of gene flow among subspecies might be possible. Due to this contradiction, more basic information to create a strong argument regarding the possibility to introduce *C. m. lengi* into Florida was needed. Thus, the objective of this research was to compare the development, oviposition, and feeding behavior of *C. m. fusicilabris* and *C. m. lengi*, on the cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae) as prey in the feeding behavior study, and strawberry, *Fragaria* × *ananassa* Duchesne, as a substrate. Strawberry plants were maintained following Paranjpe (2003) protocols. Experiments were conducted at the biological control laboratory, Protected Agricultural Project Research Station, University of Florida, Horticultural Sciences Department in Gainesville, FL. Both subspecies of *C. maculata* were provided by Entomos (Gainesville, FL) (voucher specimens can be found at DPI) where they were reared on undisclosed artificial diet.

From an initial colony (40-50 females per cage) from Entomos, 20 egg masses of *C. m. fuscilabris* and 20 of *C. m. lengi* were randomly selected and isolated in individually labeled 10-cm diameter Petri dishes and maintained at 26 ± 1°C, 80 ± 5% R.H., and 16:8 h (L:D) photoperiod. Eggs were checked for larval eclosion every 12 h. After eclosion, 20 larvae were collected randomly and isolated in 30 ml plastic cups. Larvae were fed every second day with an undisclosed proprietary artificial diet

(1.8 g), to which were added bee pollen (0.05 g) and shrimp eggs (0.01 g). Water was provided through wet cotton balls. Larvae were transferred to clean plastic cups twice a week. Daily observations were made and the number of days from instar to instar was recorded. Instars were distinguished by the presence of cast exuvia. After adults emerged, one female and one male were paired (n = 20) in 30-ml plastic cups for 48 h to facilitate mating. Gender was determined by examining the last abdominal sclerite under a dissecting microscope. After 48 h, females were isolated in plastic cups (15 × 15 × 10 cm) to determine viability of eggs (% eclosion), survival (larva to adult), number of egg masses, and number of eggs per mass produced by each female. A small piece of gray, thick fur served as an oviposition substrate. Longevity of adults also was measured. The experiment was repeated three times with 20 replications per treatment. The data are presented as average (±SE) over the three experiments ($P \leq 0.05$). The measure of the developmental time was analyzed by t-test for independent samples. In general, there were no significant differences between the developmental periods (egg to adult) of *C. m. fuscilabris* (23 ± 4 days) and *C. m. lengi* (22 ± 3). There were no significant differences between *C. m. fuscilabris* and *C. m. lengi* in development periods of their eggs (3 ± 3; 2 ± 1, respectively), 1st (3 ± 2; 3 ± 1) 2nd (4 ± 1; 3 ± 1), 3rd (4 ± 1; 5 ± 1) and 4th instar (3 ± 1; 3 ± 1) larval; pre-pupal (3 ± 2; 3 ± 1) and pupal stages (3 ± 2; 3 ± 1). Female adult longevity is significantly greater in *C. m. lengi* (43 ± 6 days) as compared with *C. m. fuscilabris* (38 ± 7). However, there was no significant difference between male adult longevity in the two subspecies (*C. m. fuscilabris*, 31 ± 5 days; *C. m. lengi* 36 ± 4). The percentage of eclosion of *C. m. fuscilabris* eggs to larvae (95 ± 3) was greater than of *C. m. lengi* (86 ± 4); in contrast, the percentage of survivorship (larva to adult) was significantly greater among *C. m. lengi* (73 ± 5) than among *C. m. fuscilabris* (65 ± 3). The number of egg masses produced by *C. m. lengi* per female per day (3 ± 1) was not significantly different from those produced by *C. m. fuscilabris* (4 ± 1). However, there were significantly more eggs oviposited in each *C. m. fuscilabris* mass (11 ± 3) than in each *C. m. lengi* egg mass (8 ± 3). Also, there was significantly more estimated number of eggs produced by *C. m. fuscilabris* (1,672 eggs) than *C. m. lengi* (1,032) over the female's lifetime.

An experiment was conducted to determine the consumption of *A. gossypii* by *C. m. fuscilabris* and *C. m. lengi*. Each experimental unit consisted of a 10-cm diameter Petri dish, where one strawberry leaflet, one individual of a single predator subspecies, and ten prey were placed. All instars and the adults of each subspecies were evaluated. The predators tested were starved for 8 h prior to providing them with *A. gossypii*. Ten individual prey, without a predator, per Petri dish served as a control for the experiment. Aphids were removed from infested leaves in the colony by using a wet, fine, camel hair brush. The strawberry leaflets were isolated with lanolin to confine the prey on the upper side of the leaf relative to the Petri dish. Petri dishes were sealed with Parafilm® and labeled. Each experiment was maintained at 21 ± 2°C, 65 ± 5 % R.H., and 16L: 8D photoperiod. Samples were examined under a stereo microscope and the number of prey consumed at 24 h was recorded. Each experiment was repeated three times with five replications per treatment in a block design. The feeding data are presented as average number (±SE) of prey consumed by a predator at 24 h. All data were analyzed with SAS (SAS Institute 2000). The general linear model (GLM) procedure was used to construct analysis of variance (ANOVA). Averaged over all five feeding stages, *C. m. fuscilabris* consumed more aphids (8.4 ± 1.1) than did *C. m. lengi* (6.5 ± 1.5) (LSD, 0.05 = 1.96; $F = 1.19$; $df = 2, 20$; $P > 0.09$) in 24 h (Table 1). Aphid consumption by *C. m. fuscilabris* 1st instar was significantly greater as compared with *C. m. lengi* ($F = 1.84$; $df = 4, 20$; $P >$

TABLE 1. CUMULATIVE AVERAGE CONSUMPTION (MEAN ± SE) BY TWO SUBSPECIES OF *COLEOMEGILLA MACULATA* DE GEER (COLEOPTERA: COCCINELLIDAE) PREYING ON THE COTTON APHID, *APHIS GOSSYPII* GLOVER (HOMOPTERA: APHIDIDAE), DURING 24 H (N = 10).

	Number of Aphids Consumed		
Life Stage	*C. m. fuscilabris*	*C. m. lengi*	Significance
1st instar	7 ± 1	4 ± 1	n.s.
2nd instar	9 ± 1	7 ± 2	n.s.
3rd instar	9 ± 1	8 ± 1	*
4th instar	9 ± 1	7 ± 1	*
adults	9 ± 1	7 ± 1	*
Total	9 ± 1	7 ± 1	*

Mean (± SE) within subspecies. Each treatment was repeated three times with five replications in each treatment. n.s. = no significant different; * = significant different ($P < 0.05$)

0.06). Also, *C. m. fuscilabris* 4th instar consumption of aphids was greater than that of the 4th instar of *C. m. lengi* ($F = 3.84$; $df = 4, 20$; $P > 0.05$) and adult *C. m. fuscilabris* consumed more aphids than did adult *C. m. lengi* ($F = 3.84$; $df = 4, 20$; $P > 0.05$). *C. m. fuscilabris* 2nd and 3rd instar consumption of aphids was not significant different from that of 2nd and 3rd instar of *C. m. lengi* ($F = 3.04$; $df = 4, 20$; $P > 0.126$ and $F = 2.02$; $df = 4, 20$; $P > 0.15$, respectively).

Although immature and adult *C. m. lengi* are larger than those of *C. m. fuscilabris* (Peres 2000), this morphological advantage does not provide any significant benefit to *C. m. fuscilabris* as compared with *C. m. lengi*. For instance, considering total egg production as a measure of a successful candidate for mass rearing for commercial purposes, our data indicated the advantage of *C. m. fuscilabris* as a mass reared subject. The 38-day life of *C. m. fuscilabris* and 43-day life of *C. m. lengi* adults were lower as compared with the 3 months reported by Wright & Laing (1978). We also observed a 3-day pre-ovipositional period in contrast to the 5 to 15 days reported by Hodek (1973). This situation may have occurred because our insects came from a commercial colony fed on an artificial diet for many generations. In nature, *C. maculata* spends time selecting ovipositional sites based on availability of food such as aphids and eggs of various species (Nault & Kennedy 2000). Our observations indicated that *C. m. fuscilabris* seems to be more aggressive than *C. m. lengi* (unpublished data). *C. m. fuscilabris* take only few second before starting to manipulate and consume (handling time) the prey (Rondon et al. 2004) as compared with *C. m. lengi*. Although no striking advantages emerged for one subspecies over the other, further studies are still needed. Results form our laboratory experiments provide the basis to further evaluate the possible introduction of *C. m. lengi*.

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Summary

After measuring the developmental time, reproduction, and feeding of both subspecies of *C. maculata*, we conclude that there were no significant differences between subspecies in developmental periods but there were different levels of female longevity, eclosion, survival, and number of eggs per mass. In general, *C. m. fuscilabris* consumed more *A. gossypii* than *C. m. lengi* in 24 h and produced more eggs per female. Further studies are needed to conclude if the introduction of *C. m. lengi* into the ecosystem of Florida would bring additional benefits to the present predator complex.

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DAMAGE IN CENTIPEDE SOD ASSOCIATED WITH CRANE FLY AND MARCH FLY LARVAE (DIPTERA: TIPULIDAE, BIBIONIDAE) IN MISSISSIPPI

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Crane flies (Diptera: Tipulidae) are distributed worldwide, ranging from fresh and marine aquatic habitats to drier terrestrial environments (Alexander & Byers 1981). Tipulidae is the largest family in the Diptera; however, larvae have been described for less than 10% of the named North American species (Thompson 1990). Larvae of a few *Tipula* species have been implicated in damage to crops and grasslands in North America (Hartman & Hynes 1977; Alexander & Byers 1981; Alexander 1920). Larvae of the range crane fly, *T. (Triplictipula) simplex* Doane, a native species, consume roots causing damage to unirrigated pastureland in the San Joaquin Valley, California (Hartman & Hynes 1977). Larvae of other native *Tipula (Serratipula)* species have been implicated in pasture damage (Alexander 1967; Gelhaus 1986). Two exotic species, the common and the European crane fly *(T. oleracea* L. and *T. paludosa* Meigen, respectively) are destructive pests of cool-season turfgrass in the Pacific Northwest, western New York (D. Peck, Cornell University, personal communication), and maritime provinces of Canada (Jackson & Campbell 1975; Vittum et al. 1999; LaGasa & Antonelli 2000).

Larvae of march flies (Diptera: Bibionidae) are herbivores and scavengers (Hardy 1981). Larvae of several species have been reported to damage agronomic crops, vegetables, and grasses (Hardy 1981; Darvas et al. 2000). In the southeastern United States, swarms of adult *Plecia nearctica* Hardy, or lovebugs, are abundant in the spring and fall. Larvae of *P. nearctica*, however, are not a known pest of turfgrass.

On 13-I-2004, three larvae of the subgenus *Tipula* (*Triplicitipula*) were collected from a group of about 30 larvae crossing pavement adjacent to a bermudagrass home lawn in Saucier, Harrison County, MS. No damage to the adjacent grass was noted. At that same site on 31-I-2004, adult *T. (Triplicitipula) umbrosa* Loew were collected at dusk and presumed to be conspecific with the larvae collected earlier. Females were typically collected while at rest on a vertical surface such as a building. Males were collected most often while copulating with females. This marks the first record of this species in Mississippi; the species is known previously from Louisiana and Florida (Oosterbroek 2003).

On 27-II-2004, live larvae and pupae (Tipulidae and Bibionidae) were collected by Wayne Wells from under centipede grass (*Eremochloa ophiuroides* [Munro] Hack.) sod which was severely weakened from extensive root herbivory and poor nutrition. The infested turf, growing on a sod farm in Picayune, Pearl River County, MS, was breaking apart during harvesting, indicating damage to the roots. That same day, specimens were submitted to the senior author for identification. Most of the live immatures were placed into a mixture of moistened field soil and sand in the laboratory for rearing. A few representative larvae and pupae were preserved in alcohol.

On 4-III-2004, the previously mentioned sod farm was surveyed by the senior author. This site contained three separate fields of centipede grass where the root damage was such that they were deemed unharvestable by the sod producer. Because larvae of Tipulidae and Bibionidae are not commonly associated with damage to warm season grasses, the site was first surveyed for damage from more common pests such as mole crickets (Orthoptera: Gryllotalpidae, *Scapteriscus* spp.), white grubs (Coleoptera: Scarabaeidae), or billbug larvae (Coleoptera: Curculionidae). In each field, three 1-m^2 areas of damaged turf were sampled with a soap solution for disclosing mole crickets and adult billbug (Vittum et al. 1999). Three soil samples, consisting of 0.1-m^2 plots, were excavated on each of three infested fields and the soil, grass, and thatch examined for larvae.

Disclosing samples yielded no mole crickets or billbugs, and only immature flies were recovered from excavated samples. Spiny brown larvae (Bibionidae) formed aggregations (about 5-10 larvae) in, or just below, the thatch. Larvae in some aggregations appeared white, not light brown, and appeared likely infected with an entomopathogen. Larger larvae and pupae (Tipulidae) also were located in the thatch, but solitary. None of these larger larvae appeared infected. Both types of larvae and the *Tipula* pupae were collected for rearing. About half of the immatures that were collected that day were packaged into loose, moist soil and shipped overnight to the lab-

oratory of JKG, The Academy of Natural Sciences, Philadelphia for rearing. The remaining immatures were confined with a core of grass in a sealed plastic container and reared in the laboratory at the Coastal Research & Extension Center, Biloxi. Several crane flies emerged in early March from pupae at both laboratory locations and were confirmed by JKG to be *Tipula umbrosa*.

All bibionid larvae at both locations died before eclosion. Cadavers were firm but within a few days became enveloped in a white fungal growth, presumably the same pathogen noted in the field. A fungus from these cadavers was isolated by Dr. Charlotte Nielsen (Cornell University) and identified by Dr. Richard Humber (USDA, ARS, Ithaca, NY), as *Evlachovaea* sp. Species identification of these larvae was not possible without an adult specimen. However, JKG could identify them as members of the genus *Plecia*, likely larvae of the lovebug, *P. nearctica*, which is abundant in Mississippi in the spring and fall.

This is the first record of *T. umbrosa* in Mississippi and the first habitat record for larvae of this species. Closely related adults and larvae (*Triplicitipula*) in the eastern United States may also develop in grassy areas, particularly at edges of woodlands; the more distantly related species in the western United States include those that are the pest "range crane flies" (Gelhaus 1986). Although not previously recorded as pests of turfgrass, we document that larvae of both *T. umbrosa* and *Plecia* sp. can be associated with damage to warm season grasses, especially those with already weakened root systems or under nutrient stress.

We thank Billy Joe Lee, Paul Jeaufreau, and Wayne Wells (Mississippi State University, Department of Plant and Soil Sciences) for collecting specimens and assistance with the site survey. Identifications of all larvae and adults were made by JKG. We thank Ann Hajek, Cornell University, for arranging for the identification of the fungal pathogen, and George Byers, University of Kansas, for comparing specimens of *T. umbrosa* with those he identified from Louisiana. JKG also consulted an unpublished manuscript by Steven Teale reviewing the eastern Nearctic species of *Tipula (Triplicitipula)* for help in identifying *T. umbrosa*. Voucher specimens of *T. umbrosa* and *Plecia* sp. are on deposit in the collection of The Academy of Natural Sciences and in the Mississippi Entomology Museum, Starkville. Richard Brown, Mark Woodrey (Mississippi State University), and David Boyd (USDA-ARS) provided helpful comments on an earlier draft of this manuscript. This paper is No. J-10723 of the Mississippi State Agricultural Experiment Station.

Summary

Larvae of march and crane flies (Bibionidae, *Plecia* sp. and Tipulidae, *Tipula (Triplicitipula) umbrosa* Loew) were collected from beneath damaged, low maintenance centipede grass sod in Picayune, Mississippi. Larvae of both species have not been associated previously with turf damage. Larvae and adult *T. umbrosa* also were found associated with turf in a residential landscape in Saucier, MS. This is the first record of *T. umbrosa* for Mississippi and a new record of larval habitat.

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SURVEY OF IMPORTED FIRE ANT (HYMENOPTERA: FORMICIDAE) POPULATIONS IN MISSISSIPPI

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The red imported fire ant (RIFA), *Solenopsis invicta* Buren, has been encroaching on the range of the black imported fire ant (BIFA), *Solenopsis richteri* Forel to the extent that the current range of BIFA is limited to only three states: northern Mississippi, northwestern Alabama, and southern Tennessee. In Mississippi where the two species coexist, evidence of hybridization has been reported (Vander Meer et al. 1985; Ross et al. 1987). These two species produce reproductively viable F1 hybrids that were found to occupy a broad band across the northern tier of Mississippi, Alabama, and Georgia (Diffie et al. 1988). The objective of this study was to determine the distribution of the RIFA, BIFA, and hybrid populations in Mississippi.

Study Site: Samples of worker ants were collected from field colonies in northern and central Mississippi. Mounds were mapped with a backpack Trimble 124 beacon DGPS system utilizing GIS Solo CE V3.0 software (TDS) installed on a Compaq iPAQ Pocket PC H3900 series. A vial sample containing 100-1000 ants was removed from each mound, labeled for identification, and stored on ice until frozen. Frozen samples of major caste workers were examined and identified to species. Ant samples identified as *S. richteri* were analyzed by gas chromatography for venom alkaloids and cuticular hydrocarbons (Vander Meer et al. 1985). These two classes of compounds readily distinguish BIFA and hybrid ants which are morphologically identical. Field data and the results from species and hybrid identification were entered into ArcView 3.2a Geographic Information Systems (GIS) for analysis, and for spatial presentation of the data.

The distribution of RIFA, BIFA, and hybrid populations in Mississippi for 2001-2003 are shown in Fig. 1. A total of 176 mounds were surveyed from 52 counties in Mississippi. An earlier report found hybrid populations in five counties from northeastern Mississippi (Diffie et al. 1988). In this investigation, hybrid populations were found in twenty-seven counties extending as far west as Bolivar County in the Mississippi Delta (Fig. 1). Earlier reports showed BIFA populations in eight counties of northeast Mississippi (Diffie et al. 1988). In this investigation, BIFA populations were found in twenty-two counties extending northwest to Tunica and De Soto County, and as far south as Noxubee County in eastern Mississippi. RIFA populations were found as far north as Bolivar County in west Mississippi. However, the northeast range of RIFA populations extends to Kemper County. RIFA populations further south in Mississippi extend throughout the central and southern region of the state (Fig. 1).

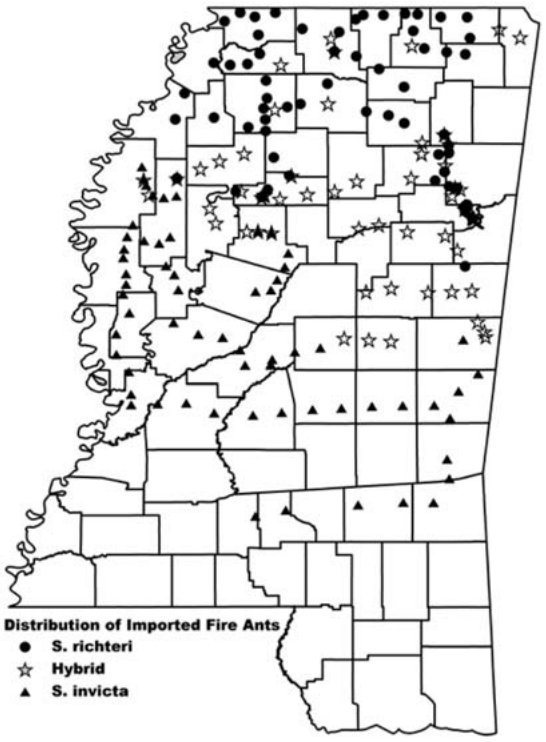

Fig. 1. Spatial distribution of *S. richteri*, *S. invicta*, and hybrid imported fire ant colonies within Mississippi counties, 2001 to 2003.

Several general conclusions can be reached regarding the distribution of imported fire ants in Mississippi. RIFA populations extend further north in the west than in east Mississippi, whereas BIFA/hybrid populations extend further south in eastern than in western Mississippi and can be found in several northwestern counties.

This shift in spatial distribution for RIFA, BIFA, and hybrid populations in Mississippi suggests that BIFA populations will eventually be replaced by RIFA and hybrid populations in Mississippi and perhaps even in the United States. Currently the RIFA and hybrid populations extend further north in the western part of Mississippi, whereas in the eastern part of Mississippi the BIFA/hybrid populations extend as far south as Noxubee County. The distribution RIFA, BIFA, and hybrid populations can have a significant effect on the implementation of an areawide program to manage fire ants in Mississippi. Vogt et al. (2004) listed several of these factors, including sampling, treatment thresholds, and biological control agents. The presence of RIFA, BIFA, and/or hybrid populations at a release site for biological control agents would prove critical in targeting specific fire ant populations because most biological control agents are relatively host specific.

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Summary

This study determined the distribution of the red and black imported fire ant, and their hybrid ant populations in Mississippi. The range of black imported fire ant populations was found to extend to twenty-two counties, whereas hybrid populations were found in twenty-seven counties in Mississippi. The distribution of species and hybrid fire ant populations will be important in the development of area-wide programs to control imported fire ants in this area of the United States.

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OCCURRENCE OF FRUIT FLIES (DIPTERA: TEPHRITIDAE) IN THE STATE OF ALAGOAS, BRAZIL

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The northeastern region of Brazil produces a substantial amount of fruit because of its climate, soil fertility, and good irrigation programs. However, as fruit production increases, so do tephritid fruit flies populations. Pest fruit flies occur in seven of the nine states that belong to this northeastern region, especially the following species: *Anastrepha fraterculus* (Wiedemann 1830), *Anastrepha sororcula* (Zucchi 1979), *Anastrepha obliqua* (Macquart 1835), and *Ceratitis capitata* (Wiedemann 1824) (Malavasi et al. 2000). In spite of the pest status of *C. capitata* and *Anastrepha* species in the State of Alagoas, no publication reporting their occurrence in Alagoas exists (Malavasi et al. 2000; Zucchi 2001).

Anastrepha fraterculus, *A. obliqua*, *A. sororcula* and *C. capitata* are of quarantine importance in many countries, especially the last species, due to the rigorous restrictions (Araújo et al. 2000; Sales & Gonçalves 2000). In Brazil, *C. capitata* and *A. fraterculus* severely damage only temperate fruit cultivations in the southeastern and southern regions, respectively. *Anastrepha obliqua* and *A. sororcula* have been considered as secondarily important pests (Malavasi et al. 2000). However, the expansion of fruit production in the northeastern region may change this situation. Therefore, a survey of tephritid populations is necessary in order to develop control strategies for these pests in all states of the region.

Severely infested fruits from unmanaged cultivars which belong to four plant species (*Mangifera indica* L- var. *ligata*, *Averrhoa carambola* L., *Psidium guajava* L. var. *paloma*, and *Jambosia* sp. L.) were collected from three families located in six estates in Alagoas (Maceió, 09°39'57"S/35°44'07"W; 16 m, Rio Largo, 09°28'42"S/35°51'12"W; 39 m, Paripueira, 09°28'30"S/35°32'30"W; 5 m, Arapiraca, 09°45'09"S/36°39'40"W; 264 m, Coruripe, 10°07'32"S/36°10'32"W; 16 m, and União dos Palmares, 09°09'46"S/36°01'55"W; 155 m) from February 2000 to July 2001. In total, thirty kilograms of infested fruits were collected, with an average of four larvae/fruit. The fruits were placed in containers with a layer of vermiculite as a pupation medium, and pupae were held in plastic boxes until emergence of adults. Voucher specimens were deposited at the Departamento de Entomologia, Fitopatologia e Zoologia Agrícola, Escola Superior de Agricultura Luiz de Queiroz (ESALQ), Universidade de São Paulo, Piracicaba, SP, Brazil. Identification of fruit flies was carried out by Dr. Roberto Antônio Zucchi on the basis of the morphological characteristics of the female ovipositor.

We report the presence of pest fruit flies for the first time in the State of Alagoas. *Anastrepha fraterculus*, *A. obliqua*, *A. sororcula*, and *C. capitata* were identified. *Anastrepha obliqua* and *A. fraterculus* infested all the fruits collected. In guavas the number of *A. fraterculus* was higher than that of *A. obliqua*. In the remaining host fruits, *A. obliqua* was the predominant species. *Anastrepha sororcula* was found in fruits of the Myrtaceae family (guavas and "jambos"). *Ceratitis capitata* was reared only from starfruits. *Anastrepha obliqua* and *C. capitata* were recovered in the largest numbers. In addition, a fruit fly parasitoid *Doryctobracon areolatus* Szépligeti (1911) (Hymenoptera: Braconidae) was found (Table 1). All parasitoids were associated with *Anastrepha* spp.

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SUMMARY

The occurrence of *Anastrepha fraterculus*, *A. obliqua*, *A. sororcula*, and *Ceratitis capitata* is reported for first time in the State of Alagoas. The specimens were obtained from starfruits *A. carambola*, guavas *P. guajava*, mangoes *M. indica*, and "jambos" (*Jambosia* sp.). The parasitoid *Doryctobracon areolatus* was recorded attacking the *Anastrepha* species.

TABLE 1. FRUIT FLIES AND ASSOCIATED PARASITOIDS COLLECTED FROM FRUITS IN MACEIÓ, RIO LARGO, PARIPUEIRA, ARAPIRACA, CORURIPE AND UNIÃO DOS PALMARES, ALAGOAS, BRAZIL.

Host family	Host species	Species		Number of females (F) and males (M)
		Fruit fly	Parasitoid	
Anacardiaceae	*Mangifera indica* L.	*A. obliqua*	—	15F; 18 M
		A. fraterculus	—	1F
Myrtaceae	*Jambosia* sp.	*A. obliqua*	—	14F; 12M
		A. fraterculus	—	11F; 10 M
		A. sororcula	—	02F; 01M
	Psidium guajava L.	*A. fraterculus*	—	121F; 95M
		A. obliqua	—	25F; 21M
		A. sororcula	—	10F; 07M
		—	*D. areolatus*	23F; 15M
Oxalidaceae	*Averrhoa carambola* L.	*A. obliqua*	—	174F; 169M
		C. capitata	—	155F; 162M
		A. fraterculus	—	04F; 02M
		—	*D. areolatus*	18F; 08M

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LABORATORY REARING PROCEDURES FOR TWO LEPIDOPTERAN WEED BIOCONTROL AGENTS

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Most noxious weeds infesting rangeland are exotic species (DiTomaso 2000). The genus *Centaurea* which contains several species of knapweed is the most abundant group in the western United States (Skinner et al. 2000). In their native habitat of Eurasia, natural enemies have prevented knapweed from becoming an economic problem (Keane & Crawley 2002). However, in the United States where they were accidentally introduced more than 100 years ago, these weeds, in the absence of their natural enemies, have reproduced unchecked and replaced many of the more desirable rangeland vegetation. Biological control of weeds with imported insects and pathogens is safe, environmentally sound, and cost effective (McFadyen 1998), and importation and use of highly host-specific biological control organisms offers considerable promise for weed control. Thirteen insect species have been imported into the US from Eurasia for control of knapweeds (Lang et al. 2000). Releases of some of these species on a Colorado grassland reduced diffuse knapweed by 77% of absolute cover (Seastedt et al. 2003). However, a major constraint to the widespread use of these biocontrol agents is the lack of sufficient numbers of insects for release. Story et al. (1994) produced 20,000 adults of *Agapeta zoegana* on spotted knapweed planted in field cages at a cost of $1.32/insect. Since artificial rearing has been used to mass-produce insects that are comparable to wild populations, at a reasonable cost (Leyva et al. 1995), it would be desirable to develop artificial diets to rear some of the weed-feeding insects.

Pterolonche inspersa (Lepidoptera: Pterolonchidae) that feeds both internally and externally on diffuse knapweed roots and *A. zoegana* (Lepidoptera: Tortricidae) that feeds on the roots of spotted knapweed, were selected for this study based on their host specificity and efficacy. Schroeder (1977) considered *P. inspersa* to be one of the most promising candidates for the biological control of diffuse knapweed in North America. In both species, rosettes were preferred for oviposition as well as feeding by newly hatched larvae. In northern Greece, *P. inspersa* was reported to be univoltine, diapausing during the winter months as 3rd instars (Campobasso et al. 1994; Dunn at al. 1989). *A. zoegana*, which has six instars, can complete 2-3 generations per year in Europe (Müller et al. 1988), whereas in British Columbia, it is restricted to only one generation (Muir & Harris 1987). However, there is little information on the nature of the diapause and no descriptions of rearing methodology for either of these species. We report here that both species can be reared from the egg to the adult stage on artificial diet and that diapause can be averted or shortened under our rearing conditions.

Adults of *P. inspersa* and *A. zoegana* were collected from diffuse and spotted knapweed in western Montana during June of 1997. The moths were placed in 500-ml cylindrical paper oviposition containers lined with wax paper, provided with 10% honey for food, and shipped overnight to the USDA-ARS Insect Biocontrol Laboratory, Beltsville, MD. The containers were held at 28° ± 2°C, 55 ± 10% RH and a photoperiodic regimen of LD 15:9. Eggs were removed every third day and transferred to Petri dishes lined with moist filter paper. Newly hatched larvae were placed directly on diet. Because there was no artificial diet available for any insect in the family Pterolonchidae, we obtained a diet developed for the pink bollworm, *Pectinophora gossypiella*; another member of the superfamily Gelechioidea. Similarly, for *A. zoegana*, we obtained diet developed for another member of the Tortricid family, the Eastern spruce budworm, *Choristoneura fumiferana*. Both these diets were purchased from Southland Products, Lake Village, AR. Recipes for the *P. gossypiella* and *C. fumiferana* diets can be found in Bartlett and Wolf (1985) and in Robertson (1985), respectively. Roots of knapweed, obtained from Montana, were washed, freeze-dried, and powdered in a grinder. Diets were prepared with or without 2% root powder. Following testing of the first batch of diets, we reduced the water content by 10% (from 930 ml recommended by Southland Products to 835 ml per liter of diet). Three types of containers; wax coated paper straws (7 mm in

diam × 10 cm long), borosilicate glass culture tubes (10 × 75 mm) and 30-ml clear plastic cups with paper lids (BioServ, Frenchtown, NJ) were tested for suitability in rearing both species. All test containers were filled with diet and infested with either 1 or 4 larvae. The straws were placed in desiccators containing water, and together with tubes and cups kept in an environmental chamber maintained at LD 15:9 and temperatures of 30° ± 2°C and 25° ± 2°C during the light and dark cycles, respectively. Subsequently, 131 cups containing pink bollworm diet and 509 cups containing Eastern spruce budworm diet, both with and without 2% root powder were infested with *P. inspersa* and *A. zoegana* larvae, respectively. The containers were examined every 10 days for 50 days. Some of the larvae/pupae were shipped to Sidney, MT. Whereas adults were allowed to emerge from the pupae, the cups with larvae were placed in a refrigerator (3°C) for 86 days to provide for diapause, after which time the cups were returned to 28°C to promote further development.

Hatch was high (> 80%) if eggs were placed on moist filter paper in Petri dishes. Since both species were root feeders, we first chose to test diet-filled straws, thus providing conditions for rearing that simulated the natural environment. However, the straws became moldy even though the diet was prepared and the straws filled in a laminar flow hood. Culture tubes were also inappropriate as rearing vessels because the tubes retained too much moisture and the larvae invariably drowned. Only approximately 10% of *P. inspersa* and 2% of *A. zoegana* reached the 2nd instar in tubes, even in the presence of root powder. Growing larvae in plastic cups with paper lids was the most effective method tested. A comparison of results from experiments in which 1 *vs* 4 larvae were placed in each cup of the appropriate diet showed that no more than one larva survived and grew to maturity. While both species of larvae remained alive for several weeks on diets in which root powder was omitted, insect growth was considerably slower than when root powder was present in the diet. With the incorporation of root powder, the larvae initiated feeding and tunneled into the diet. Whereas 6.1% of *P. inspersa* larvae grew to 3rd or higher instar on diet without the root powder, 33.3% did so when root powder was incorporated into the diet. Larvae molted 4 times and reached the 5th instar in approximately 50 days. These 5th instars contained large amounts of fat and their mean length was 8.6 mm (Fig. 1A). Percent survival of *A. zoegana* was lower than that of *P. inspersa*, i.e., 9.1% of the larvae placed in cups containing the Eastern spruce budworm diet with root powder survived beyond the 3rd instar. The mean length of *A. zoegana* 4th and 5th instars was 6.0 and 9.1 mm, respectively, and it took approximately 45 days for larvae to reach the 5th instar (Fig. 1B). Larvae of both species spun silk sheaths during feeding, and removal from their sheaths often resulted in larval death. Less than optimal percentages of survival were due in large part to high mortality of first instars. In our study, two factors appeared to con-

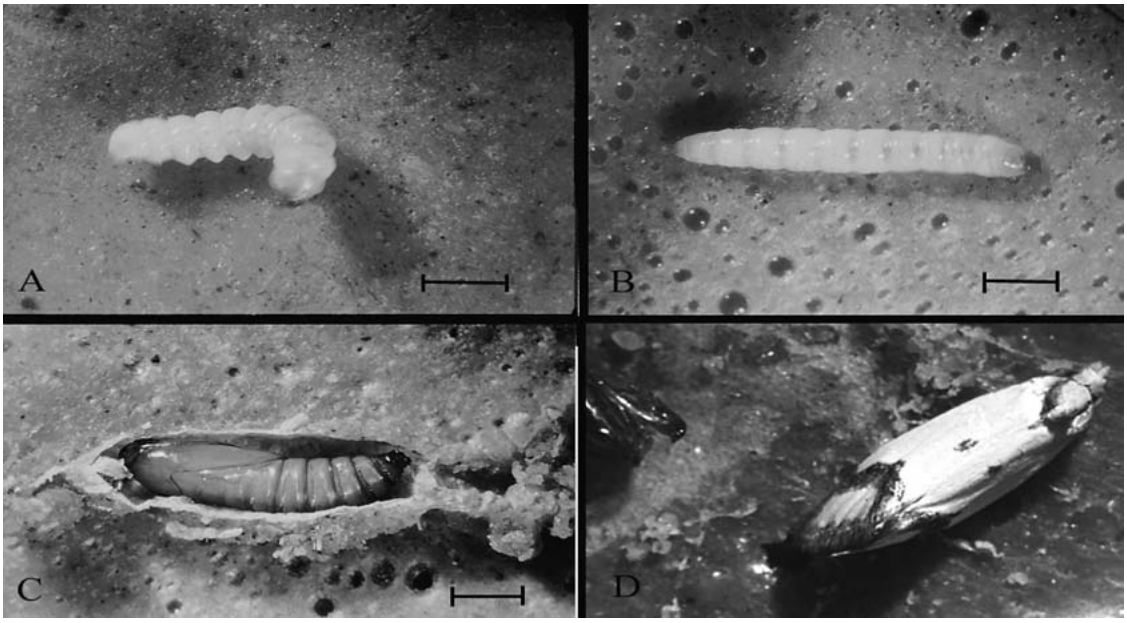

Fig. 1. *Pterolonche inspersa* and *Agapeta zoegana* reared on their respective artificial diets. A. 5th instar of *P. inspersa*. Note the accumulated fat in the body. B. 5th instar of *A. zoegana*. C. pupa of *A. zoegana*. Scale bars = 2 mm. D. Adult *A. zoegana* newly eclosed from the pupa.

tribute to high mortality; drowning in droplets of moisture and lack of immediate feeding. Lowering the moisture content of the diets by 10% and allowing the diets to dry for one hour before infesting with larvae reduced mortality. Although 2% root powder was incorporated into the diets, apparently it did not provide sufficient stimulation for a large percentage of the newly hatched larvae to feed. Because the young larvae of both species mine in the rosette leaves before they tunnel into the roots (Müller et al. 1988), it is possible that some chemical factor present in the leaves, but absent in the roots, may be acting as an initial feeding stimulant. It is suggested that in future studies, two diets, one with root powder as used above and a second one with 2% freeze-dried powdered young leaves of corresponding plants be prepared and poured as two layers into 22 × 52 mm plastic tubes (BioQuip, Gardena, CA) or cups.

We observed three *A. zoegana* pupae (Fig. 1C) which had apparently developed without undergoing diapause. The remaining *A. zoegana* and all of the *P. inspersa* larvae entered diapause. Approximately 30 days after removing both species of larvae from the refrigerator, the first pupa appeared and within a week, the first adults began to emerge (Fig. 1D). Twenty-three and 37 adults of *A. zoegana* and *P. inspersa*, respectively, emerged from late April to early September. These adults were placed in mating cups and eggs that were laid were used to establish an F_2 generation. Data from studies performed in Europe indicate that *P. inspersa* is a univoltine species and showed that this insect enters diapause as 3rd instars (Schroeder 1977). In our investigations, some larvae developed to the adult stage without entering diapause, indicating that it is possible to select individuals from a population and use these insects to develop a non-diapause strain. We recognize that this study was not a comprehensive one. However, the basic information that we have obtained can be useful in developing mass rearing techniques for exotic biocontrol agents such as the two lepidopterans used in this study.

We thank Jim Story and Linda White (Montana Agricultural Experiment Station, WARC, Corvallis, MT) for collection and shipment of insects to Sidney, MT. Thanks are also due to Dr. Lincoln Smith, USDA, ARS, Albany, CA, and Dr. David Kazmer, USDA, ARS, Sidney, MT for critically reviewing an earlier version of the manuscript. Mention of a proprietary product is not an endorsement by the US Department of Agriculture.

Summary

Laboratory rearing methods for *P. inspersa* and *A. zoegana*, introduced into North America for the control of the exotic knapweeds, *Centaurea* spp., were developed. We used known diets for the pink bollworm and Eastern spruce budworm and added 2% knapweed root powder to these. After 45-50 days, we obtained some 4th and 5th instars of both species, which apparently either averted or shortened the diapause for these individuals.

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PROPOSAL OF A NEW NAME FOR *PHYLLODROMUS* DELEON, 1959 (ACARI: PHYTOSEIIDAE), A JUNIOR HOMONYM OF *PHYLLODROMUS* JIMÉNEZ DE LA ESPADA, 1875 (ANURA: DENDROBATIDAE)

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De Leon (1959) described the genus *Phyllodromus* with the type species, *Phyllodromus leiodis* De Leon, 1959, a phytoseiid mite [Acari: Mesostigmata] distributed in the state of Florida, USA. This genus remained monotypic for four decades. Moraes et al. (1997) described a second species (*P. trisetatus*) from the state of Bahia, Brazil. No other species has been described in, or assigned to, this genus.

During a recent revision of the taxonomy of Dendrobatidae (Amphibia: Anura), we detected that *Phyllodromus* De Leon is a preoccupied name created by Jiménez de la Espada (1875) for a genus of frogs (Type species: *Phyllodromus pulchellum*). Hence, *Phyllodromus* De Leon, 1959 (Acari: Phytoseiidae) represents a junior homonym of *Phyllodromus* Jiménez de la Espada, 1875 (Anura: Dendrobatidae).

We propose here *Leonacarus* **nom. nov**. for *Phyllodromus* De Leon, 1959, in application of the International Code of Zoological Nomenclature (ICZN 2000). The name refers to "the mite of Leon" acknowledging De Leon who described and recognized this taxon as a separated genus. The species currently included in *Leonacarus* are *L. leiodis* (De Leon, 1959) **comb. nov.**, and *L. trisetatus* (Moraes & Melo, 1997) **comb. nov**.

SUMMARY

Phyllodromus De Leon, 1959 (Acari: Phytoseiidae) is a junior homonym of *Phyllodromus* Jiménez de la Espada, 1875 (Anura: Dendrobatidae) and in application of the International Code of Zoological Nomenclature we propose the name *Leonacarus* **nom. nov**. for *Phyllodromus* De Leon, 1959. The species currently included in *Leonacarus* are *L. leiodis* (De Leon, 1959) **comb. nov.**, and *L. trisetatus* (Moraes & Melo, 1997) **comb. nov**.

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PERITROPHIC MATRIX OF THE FORMOSAN SUBTERRANEAN TERMITE (ISOPTERA: RHINOTERMITIDAE)

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The peritrophic matrix in many insects is continuously being synthesized in the mesenteron and excreted with the fecal matter (Wigglesworth 1972; Richards & Richards 1977; Tellam 1996; Lehane 1997). Peritrophic matrices are classified into 2 types according to the way they are synthesized in the mesenteron. Type I is made of concentric lamellae loosely attached to one another and synthesized by the epithelial cells through the length of the mesenteron, while type II is a single uniform layer synthesized by a group of cells in the anterior limit of the mesenteron (Wigglesworth 1972; Tellam 1996; Lehane 1997). The peritrophic matrix is most commonly made of γ-chitin, which is considerably more flexible than α-chitin while in the presence of water (Herburn 1985). Wigglesworth (1972) mentions that termites may possess type II peritrophic matrices, but this has not been confirmed. The objective of this study was to determine the type of peritrophic matrix present in *Coptotermes formosanus* Shiraki.

Formosan subterranean termites were collected from 2 different localities (City Park and Gretna) around the New Orleans metropolitan area. All the termites were brought to the laboratory in plastic containers. An infested pine log and carton nest were separately transferred to a 75.7-L plastic trash container, containing 10 L of topsoil: sand mixture at 1:1 ratio and 3 L distilled water. Pieces of wood (*Pinus taeda*, *Liquidambar styraciflua*, and *Carya illinoensis*) were added as a source of food. The containers were maintained in the dark at 27 ± 3°C for 7 d to allow the termites to settle down. Then, termites were harvested by placing pieces of wet cardboard inside of containers for 8 h. Termites were carefully removed from the cardboard pieces by gentle manual shaking.

Twenty termite workers were randomly selected and manually placed in a fixative solution of 2% glutaraldehyde, 2% paraformaldehyde, 2% acrolein, and 1.5% dimethyl sulfoxide in 0.1 M sodium cacodylate buffer (pH 7.4) (Kalt & Tandler 1971, modified). To facilitate penetration of the fixative into the termite bodies, the selected termites were decapitated under a stereo microscope and a small cut at the tip of the abdomen was made.

Fixed termite abdomens were rinsed 3 times in 0.1 M sodium cacodylate buffer, post-fixed in 1% osmium tetroxide, and embedded in Araldite/Epon epoxy resin (Araldite 502-EMbed 812) as described by Mollenhauer (1964). Abdomens were cut longitudinally producing 1-µm thick sections with an Ultracut E microtome. Five individuals were selected for sectioning based on the quality of fixation. Section series for each termite were placed on glass microscope slides, allowed to dry on a hot plate for at least 5 min, and labeled.

Sections were stained with a modification of Humphrey and Pittman's (1974) methylene blue, azure II, and basic fuchsin staining technique. This technique requires 2 stain solutions. The blue stain was prepared by mixing 0.13 g methylene blue, 0.02 g azure II, 10 ml glycerol, 10 ml methyl alcohol and 80 ml distilled water. The mixture was stirred and filtered. The red stain was prepared by mixing 0.2 g basic fuchsin in 100 ml distilled water, and diluted 1:4 in distilled water after stirring and filtering. The staining procedure was as follows: (1) The slide was flooded with blue stain for 15-60 seconds,(2) then 4-6 drops of 1% NaOH solution were added and spread over the slide by tilting it for 10 seconds, (3) slides were washed in running water and dried on a hot plate at 80°C, (4) the red stain was added for 15-30 seconds to slides on the hot plate, and (5) slides were finally rinsed with running water and dried.

Sections were examined with an optical compound microscope (Leica DMLB, Leica Microsystems, Germany) and photographed with a Leica MPS 60 micro photographic system. Color slides were produced on Kodak Elitechrome 160T. Slides were digitalized at 2,000 dpi with a high resolution scanner (Minolta Dimage Scan Multi, Konica Minolta, Japan).

Tissue coloration in sections was sufficiently consistent to differentiate basic tissues. The mesenterial epithelial cells appeared dark-blue to purple (Fig. 1A, MGE), microvilli appeared red (Fig. 1B, MV) and peritrophic matrix pink (Fig. 1A & B, PTM). Microvilli coloration was distinctive enough to make them easily identifiable. The peritrophic matrix was located next to the mass of microvilli (Fig. 1B). Fat body cells appeared pink to red in color (Fig, 1A, FBC).

The peritrophic matrix of *C. formosanus* appears to be synthesized around the invagination (Fig. 1A, FCI) of the stomodaeum into the mesenteron (Fig. 1A, MSE). A group of large pink-colored cells located around the invagination portion of the stomodaeum (Fig 1A & 1B, SC) shows

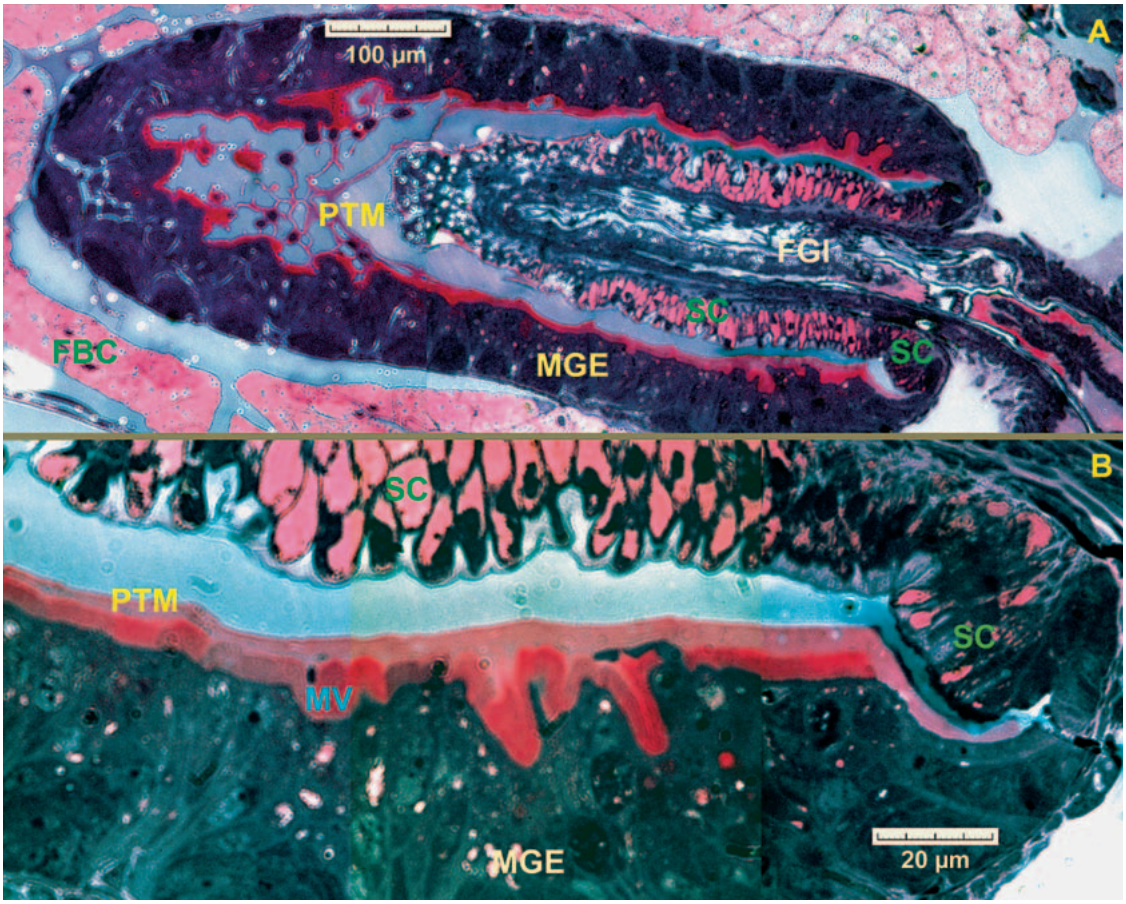

Fig. 1. Longitudinal section of foregut and midgut junction of C. formosanus workers. (A) Lower magnification showing the foregut invagination (FGI) into the midgut and midgut epithellium (MGE). (B) Higher magnification of foregut invagination showing secretory cells (SC) and peritrophic matrix (PTM). A is a composite of 2 pictures taken with a 10 × ocular and 20 × objective; B is a composite of 3 pictures taken with a 10 × ocular and 100 × objective immersed in oil.

a clear substance that migrates to the lower part of the invagination area. These cells appear to be secretory in nature producing a clear substance that is easily distinguishable (Fig. 1B). At the base of the invagination, the peritrophic matrix (PTM) seems to originate from the clear substance produced by the pink secretory cells and then covers the inner part of the mesenteron (Fig. 1B).

Our observations showed the presence of structures in the anterior part of the mesenteron resembling those described by Wigglesworth (1972) for type II peritrophic matrix (Fig. 1). Also the structure of the peritrophic matrix observed in workers of *C. formosanus* is a continuous layer instead of independent lamellae as described by Wigglesworth (1972). Based on these two characteristics, we describe the peritrophic matrix of *C. formosanus* workers as a type II.

The rate of type II peritrophic matrix production varies from 1 to 10 mm/h in different insect species (Waterhouse 1954). These production rates make type II peritrophic matrices particularly vulnerable to the action of chitin synthesis inhibitors.

Summary

The peritrophic matrix of workers of *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae) was studied from stained histological sections. Termites were decapitated, fixed in a mixture of paraformaldehyde-glutaraldehyde, embedded in epoxy, sectioned at 1 µm thickness, and stained. Our observations showed the presence of structures in the anterior part of the mesenteron resembling those described for a type II peritrophic matrix.

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FIRST REPORT OF *CONCHASPIS CORDIAE* (HEMIPTERA: CONCHASPIDIDAE) IN FLORIDA AND THE UNITED STATES

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We report for the first time the presence in Florida and the continental United States of *Conchaspis cordiae* Mamet (Hemiptera: Sternorrhyncha: Conchaspididae) (Fig. 1), an adventive scale insect species from the West Indies.

Conchaspis cordiae was described by Mamet (1954) from specimens collected in 1919 on black sage (*Cordia* sp.), and in 1917 from "mahogany" on St. Croix, U.S. Virgin Islands. It was reported also from West Indies mahogany (*Swietenia mahagoni* Jacquin) and seagrape (*Coccoloba uvifera* L.) in the Dominican Republic (Panis and Martin 1976), and has been collected in Puerto Rico and Haiti (Douglass R. Miller, personal communication). It has not been reported as a pest, and nothing is known about its biology.

Florida Department of Agriculture and Consumer Services inspector Ms. Lynda Davis made the first U.S. collection of *C. cordiae* on West Indies mahogany on November 26, 2003, in Hialeah (Miami-Dade County, FL). On February 8, 2005, Ms. Jeanette Wofford, Arborist, Department of Public Works, Cooper City, FL, called the attention of the senior author to extensive infestations of scale insects on West Indies mahoganies in Cooper City. Specimens collected from both these cities were identified as *C. cordiae* by the second author.

Having determined that it was possibly a serious pest, we conducted a preliminary survey in urban areas from Miami-Dade County to a site about 70 km north of this in southern Palm Beach County, examining West Indies mahoganies from the ground at 16 sites where at least 10 of these trees were in close proximity. Infested branches as high as 8 m from the ground were pruned with a pruning pole for obtaining specimens. Trees with infestations that we could not see or collect specimens from, i.e., restricted to branches higher than 8 m, were thus excluded from the survey. Specimens of *C. cordiae* from each locality were mounted on microscope slides and their identifications confirmed by the second author.

Based on these observations, at least one West Indies mahogany was infested with *C. cordiae* at 62.5% of the 16 sites examined, including the northernmost (26°22'N) and southernmost (25°45'N) and the easternmost and westernmost sites (80°07'W and 80°25'W, respectively) (Table 1).

To compare West Indies mahogany and several closely related species as potential hosts of this scale insect, we examined mature trees of species in the family Meliaceae at the Fort Lauderdale Research and Education Center in Davie, FL. These included 196 West Indies mahoganies, and trees interspersed with them including 14 Honduras mahoganies (*S. macrophylla* King), 29 mahogany hybrids (*S. macrophylla* × *S. mahagoni*), four African mahoganies (*Khaya nyasica* [Stapf] ex Baker f.), two tropical-cedars (*Cedrela odorata* L.), and two neem trees (*Azadirachta indica* A. Jussieu).

These observations provided two indications that West Indies mahoganies and the *S. macrophylla* × *mahagoni* hybrid are preferred hosts: (1) Infestations were found on 40.8% of the West Indies mahoganies, and 41.3% of the *S. macrophylla* × *mahagoni* hybrids, compared with 14.2% of the Honduras mahoganies, and (2) Large patches of dense populations of up to 30 mature female *C. cordiae* per cm^2 along with numerous first and second instars were visible on branches of most of the infested West Indies mahoganies and the *macrophylla* × *mahagoni* hybrids. In contrast, infestations on Honduras mahoganies were sparse and consisted of relatively few individuals per tree. One of the African mahoganies was lightly infested. No scale insects were found on Spanish-cedar or neem trees.

Conchaspis cordiae was observed on bark and not on other plant parts such as leaves or fruit capsules. Infestations were concentrated on twigs and branches up to about 6 cm in dia. Only occasional scale insects were observed on larger branches and main trunks, where they occurred in bark fissures.

Conchaspididae with about 30 described species is a small tropical family related to Diaspididae. Previously, two species have been reported in Florida: (1) *Conchaspis angraeci* Cockerell, native to the Caribbean and found on orchids and other ornamental plants (Merrill & Chaffin 1923), and (2) *Asceloconchaspis milleri* Williams,

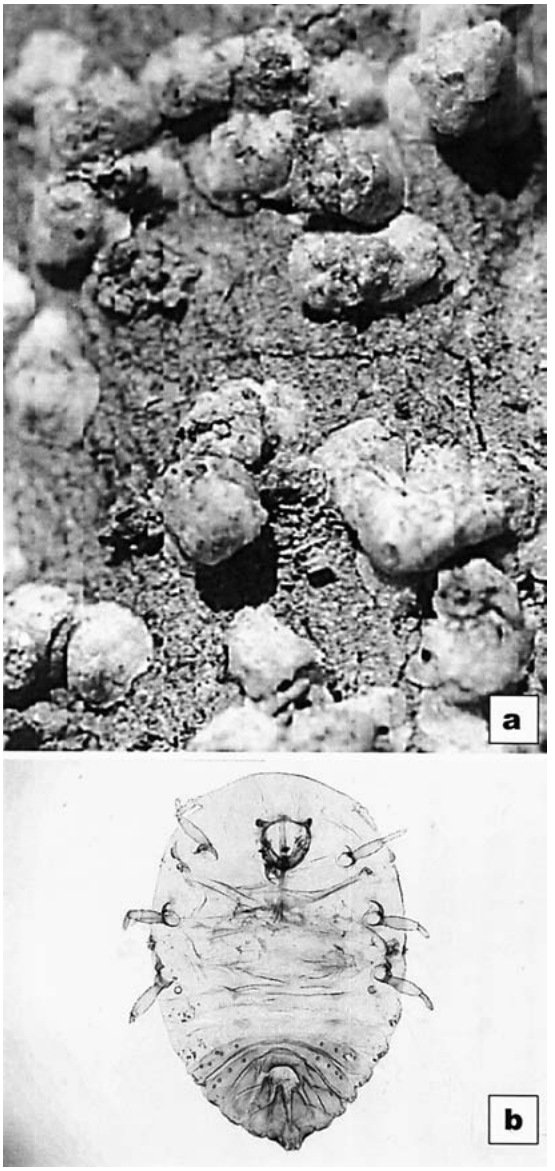

Fig. 1. West Indies mahogany scale, *Conchaspis cordiae* Mamet. (a) close-up of infestation on bark of West Indies mahogany, *Swietenia mahagoni* Jacquin, showing scale covers of mature females; (b) mature female mounted on microscope slide; the presence of functional legs in the adult female distinguishes most Conchaspididae from Diaspididae.

which was described from specimens collected in Miami on pigeonplum, *Coccoloba diversifolia* Jacquin (Williams 1992) and is not reported outside the type locality.

Previously, scale insects were rarely found on West Indies mahogany in Florida. The potential impact of this new pest on urban landscapes and the natural environment of southern Florida is not clear. We have observed heavy infestations on young West Indies mahogany seedlings, indicating that this scale insect is potentially a nursery pest. Although heavy infestations of mature trees appeared to have resulted in death of branches in only a few cases, possibly long-term infestations could result in serious damage or curtailment of growth. West Indies mahogany is a native tree in hammocks in the Florida Everglades and on the Florida Keys. It is listed as a threatened species in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Although its wild populations have been diminishing, it is one of the most popular shade trees planted in urban areas of southern Florida. Honduras mahogany has replaced West Indies mahogany as the most important tropical timber tree in the world (Mayhew & Newton 1998). Under different conditions, Honduras mahogany could possibly be more susceptible to this scale insect than our observations indicated.

Parasitoid exit holes were observed in about 5-8% of the scale coverings of mature female *C. cordiae* in samples from three sites in Broward County. Five specimens of a minute wasp were reared from *C. cordiae* in the laboratory. This species was identified as *Marietta* sp. (Hymenoptera: Aphelinidae) by the third author. We have initiated studies to elucidate the biology and ecology of *C. cordiae* and develop management options for it.

We propose the vernacular name "West Indies mahogany scale" for *C. cordiae*. This name reflects that West Indies mahogany appears to be a major host of this insect, that there are no other scale insects consistently found on this tree species, and that the scale insect itself is native to the West Indies.

We thank Dr. Douglass R. Miller, Systematic Entomology Laboratory, U.S. Department of Agriculture, Beltsville, MD, for providing Caribbean records of *C. cordiae*, and the following University of Florida, IFAS, personnel: Bryan Steinberg and Sergio Gallo for field and laboratory assistance, and Drs. Rudolph Scheffrahn and Timothy Broschat for reviewing the manuscript.

Summary

Conchaspis cordiae Mamet (Hemiptera: Conchaspididae) is reported for the first time in Florida and the Continental U.S. and found to be widely distributed in the urban areas of southeastern Florida. West Indies mahogany (*Swietenia mahagoni*) and a mahogany hybrid (*S. macrophylla* × *S. mahagoni*) apparently are preferred hosts. Honduras mahogany (*S. macrophylla*) and African mahogany (Khaya *nyasica)* were marginal hosts. *Marietta* sp. (Hymenoptera: Aphelinidae) was identified as a parasitoid of this species.

TABLE 1. LOCATIONS OF SITES IN SOUTHEASTERN FLORIDA WHERE *Conchapsis cordiae* WAS IDENTIFIED ON *Swietenia mahagoni* DURING SURVEY MARCH 10-SEPTEMBER 4, 2005.

County	Community	Coordinates	Collecting date
Palm Beach	Boca Raton	26°22'N 80°12'W	14-VI-2005
Broward	Fort Lauderdale	26°09'N 80°07'W	4-IX-2005
Broward	Plantation	26°09'N 80°16'W	19-V-2005
Broward	Sunrise	26°08'N 80°15'W	19-V-2005
Broward	Davie	26°05'N 80°14'W	15-III-2005
Broward	Dania Beach	26°04'N 80°11'W	07-VII-2005
Broward	Cooper City	26°03'N 80°25'W	10-III-2005
Miami-Dade	Unincorporated	25°91'N, 80°18'W	26-V-2005
Miami-Dade	Miami Lakes	25°54'N, 80°18'W	7-VI-2005
Miami-Dade	South Miami	25°45'N, 80°23'W	7-VI-2005

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BOOK REVIEWS

DARSIE, R. F AND R. A. WARD. 2005. Identification and Geographical Distribution of the Mosquitoes of North America, North of Mexico. University of Florida Press, 383 pp. ISBN 0-8130-274-5. Hardback. $75.00.

This book is the second edition of a book with the same title and authors. While much of this edition is a verbatim rehash of the 1980 edition, some very important changes have been made. Twelve species have been added to the book since the first edition. Changes to the text were necessary due to additional species (e.g.,*Aedes albopictus* and *Ochlerotatus japonicus japonicus*) invading different parts of this geographic region (Sprenger and Wuithiranyagool 1986, Peyton et al. 1999), new species being defined, e.g., the detection and naming of the sibling species of *Anopheles quadrimaculatus* (Reinert et al 1997), and reinstating subgenus *Ochlerotatus* to genus status (Reinert 2000). Other significant changes are: revised and completely illustrated keys for the adult females and fourth instar larvae; new user friendly geographical distribution maps for each species; and an updated systematic index table (Table 1), which includes the new species in North America.

The book is organized into 16 sections and starts with a fairly comprehensive Table of Contents, which makes finding information on the included taxa easy. Next the authors include the Preface from the first edition, which is appropriate since much of the information presented is relevant to the second edition. This is followed by a brief Preface to the second edition, which mainly acknowledges the support (financial, graphic, office and laboratory space) the authors received to complete this book. Next is a one page section on the Abbreviations of the states in the United States of America and the Provinces of Canada. This is followed by a very brief introduction, with the main changes from the first edition being an emphasis on the use of Harbach and Knight's (1980) *Taxonomists' Glossary of Mosquito Anatomy* for morphological terms and the fact that at the time of their revising the text there were 174 known species and subspecies in 14 genera and 29 subgenera in the geographic region. This introduction is followed by the Systematics section, which was the most interesting since it discusses the most important taxonomic changes made since the last edition. It includes lists and discussions of new species, species resurrected from synonymy and exotic species introduced into the United States and Canada. It also provides the reader with a better understanding of the authors' positions on the included taxa. Next are sections on the morphology of adult females and fourth instar larvae, which are followed by generic keys to the adult females and fourth instar larvae and immediately by keys to the species of each genus. Keys to *Aedes* and *Ochlerotatus* are combined. All characters used in the keys are illustrated by well done, original drawings (1045) inserted between key couplets. Keys are included for the identification of all 174 mosquito species and subspecies known to occur in North America, north of Mexico. As expected, these keys comprise nearly half the book. The sections on adult and larval morphology discuss the anatomical structures mentioned in the keys. Other than moving the Selected Bibliography of Mosquito Morphology to the back of the book, the adult morphology section is basically unchanged from the first edition. The larval morphology section has at least one confusing change of note. In describing the setae of segment X, in the first edition the authors state that the most posterior seta is designated as 4a-X; then proceeding anteriorly, they are 4b-, 4c-, 4d-X, etc. In the second edition, referring to the same figure they seemingly state just the opposite, i.e. that the most anterior seta is designated as 4a-X; proceeding posteriorly the setae are then 4b-, 4c-, 4d-X, etc. At best this is confusing; at worst a contradiction. Another apparent contradiction between the first and second editions for larval morphology are the number of pairs of setae on abdominal segments I-VII (97 vs 86). Both the adult and larval morphology discussions are followed by a series of very useful full page plates illustrating key morphological characters. Next is a section on the Geographical Distribution of the Culicidae of North America, north of Mexico. This information is provided in text, tabular and figure form. The second edition includes 134 mosquito species distribution maps compared to 41 in the first edition. This is a vast improvement. Instead of having overlapping distributions of multiple species on each map that were hard to distinguish, this edition has a separate map for most important species. Several species with limited distribution are still found on a single map but their distribution patterns do not overlap. The next section is the Selected Bibliography of Mosquito Morphology which contains important references to understand mosquito morphological terminology. This is followed by the greatly expanded section on the Bibliography of Mosquito Taxonomy and Geographical Distribution (815 vs 536 references) over the first edition. Next is an appendix which contains the locality data for the mosquito specimens used to prepare the illustrations for the keys. Then there is a very useful Index to Scientific Names, which provides

an easy way to find information on specific taxa. This index also provides useful information (in bold) to locate the appropriate geographic distribution map for each species. On the last page is a brief biography of each author.

This text is a valuable resource for anyone interested in learning about the basics of mosquito morphology and identification, this includes mosquito control personnel, beginning and advanced students, and professional medical entomologists. It is the only comprehensive, relatively up to date, book on the identification and geographic distribution of mosquitoes in North America, north of Mexico.

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TABER, S. W. AND S. B. FLEENOR. 2005. Invertebrates of Central Texas Wetlands. Texas Tech Univ. Press, Lubbock. xi + 322 pp. ISBN 13-978-089672-550-8. Paperback. $24.95 (ISBN 13-978-089672-542-3, hardback).

There are many habitats across the United States that can be considered special due to one feature or another. Large numbers of these areas are unique in that they possess an assemblage of organisms not found in the surrounding areas, if at all outside these particular habitats. Generally, these habitats are novel in obvious ways, i.e., isolated dune systems, cave systems, sinks, bogs, or springs. The locations of these interesting ecosystems are often known only to a select few who are intimately familiar with the particular region and its flora and fauna. If the location and unique nature of these important areas were documented and readily available, these habitats would undoubtedly receive more attention from local property owners, naturalists, conservationists, scientists, and the general public. This attention is sorely needed in order to draw attention to the conservation and wise management of our natural resources as well as to educate both children and adults about the unique organisms that live in or near their own backyards. Additionally, these areas have much to contribute to our understanding of the ecology and biodiversity of these unique assemblages of organisms. Perhaps the best way to raise public awareness is to produce a field guide that focuses on these areas. This is exactly what S. Welton and S. Fleenor have done with their "Invertebrates of Central Texas Wetlands."

Unlike most field guides, this book is directed at the invertebrates of a particular area. While it does a good job of covering these organisms, its strength is the coverage of the Ottine wetlands as a whole. It not only discusses the region in detail but also presents photographs of various habitat types, maps, and descriptions of several specific hiking and nature trails traversing this area, all of which are extremely important for visitors. As an entomologist, I am impressed by the fact that the authors discuss legal issues such as not collecting organisms in parks and preserves without the appropriate permits and the necessity of receiving permission to enter private property. Such information is both appropriate and worth repeating.

The first chapter is a general treatment of the Ottine wetlands and does an excellent job of introducing the area, geological features, habitats and unique features. In addition, the authors also discuss the history of the biological and botanical surveys of this area. These studies span some seventy-five years and provide valuable information for anyone wishing to consult a more comprehensive list of the organisms known to occur in this area, including researchers who are interested in conducting comparative survey work to assess how the biota of the area has changed. The authors also cite and discuss studies that deal with the geology and hydrology of the area, placing this in the context of the various wetland habitats that occur in the Ottine wetlands. Wetland habitats can be quite diverse in composition with no two looking exactly alike. The authors take the readers through specific regions of the Ottine wetlands and explain the types of vegetation that can be found there, complete with photographs for those unfamiliar with specific plant species discussed, as well as pointing out what sort of geological features can be found there. Consequently, a reader fortunate enough to visit the area can be led directly to the major features that delineate each area or wetland habitat from others found close by. The book's descriptions are so clear that without even being there it is not hard to imagine what standing in the middle of the Ottine wetlands would be like. What a wonderful component to include in a field guide for such a unique area.

Each of the chapters that follow covers representatives of a specific group of invertebrates. Obviously, most focus on specific insect orders but chapters also cover crustaceans, millipedes, centipedes, spiders, scorpions, slugs, and snails. For each species represented, information is included on the organism's biology, distribution, size, and those other species easily confused with the species under discussion due to similar appearance. In addition, a color photograph is also included for each specimen to aid in identification. The obvious effort made to acquire accurate identifications by seeking out experts in the field is appreciated. The experts consulted are listed by name in the book's preface.

Another appreciated section of the book is its appendices. Appendix 1 lists the Texas-Endemic Invertebrates of the Ottine Wetlands and Appendix 2 lists the exotic invertebrates known to occur in the Ottine Wetlands. This information is of obvious value when studying species distributions and the interactions and competition between species found in a region. The encroachment of exotic species into regions of high endemism should be of concern to the ecology and conservation of these areas and the fauna that they contain.

Both the glossary and bibliography are well developed and appropriate for the subjects covered in the book. The breadth of both are important for the clear presentation of the content as well as for highlighting the resources needed by readers who want more specific information on a particular subject or taxa. Not intended as a coffee table book, the compact size of the book makes it perfect for taking into the field.

Relict ecosystems such as this one deserve more attention than they have traditionally received. This field guide will no doubt generate more interest in both nature and the unique faunal make-up of this special ecosystem, no doubt bringing the Ottine wetlands and the organisms living within to the attention of the amateur and scientific community alike. This cannot be said of many books.

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