INTRODUCTION TO INSECT BEHAVIORAL ECOLOGY : THE GOOD, THE BAD, AND THE BEAUTIFUL: NON-INDIGENOUS SPECIES IN FLORIDA

INVASIVE ADVENTIVE INSECTS AND OTHER ORGANISMS IN FLORIDA.

J. H. FRANK[1] AND E. D. MCCOY[2]
[1]Entomology & Nematology Department, University of Florida,
Gainesville, FL 32611-0620
[2]Biology Department and Center for Urban Ecology, University of South Florida,
Tampa, FL 33620-5150

ABSTRACT

An excessive proportion of adventive (= "non-indigenous") species in a community has been called "biological pollution." Proportions of adventive species of fishes, amphibia, reptiles, birds and mammals in southern Florida range from 16% to more than 42%. In Florida as a whole, the proportion of adventive plants is about 26%, but of insects is only about 8%. Almost all of the vertebrates were introduced as captive pets, but escaped or were released into the wild, and established breeding populations; few arrived as immigrants (= "of their own volition"). Almost all of the plants also were introduced, a few arrived as immigrants (as contaminants of shipments of seeds or other cargoes). In contrast, only 42 insect species (0.3%) were introduced (all for biological control of pests, including weeds). The remainder (about 946 species, or 7.6%) arrived as undocumented immigrants, some of them as fly-ins, but many as contaminants of cargoes. Most of the major insect pests of agriculture, horticulture, human-made structures, and the environment, arrived as hitchhikers (contaminants of, and stowaways in, cargoes, especially cargoes of plants). No adventive insect species causing problems in Florida was introduced (deliberately) as far as is known.

The cause of most of the so-called biological pollution is the public's demand for "pet" animals and "ornamental" plants of foreign origin, the public's environmental irresponsibility in handling these organisms, the dealers' willingness to supply these organisms for cash, and governments' unwillingness to stem the flow of a lucrative commerce. The cause of almost all of the remaining part is flight, walking, swimming, and rafting from adjoining states and from nearby countries in the Caribbean, Mexico and Central America. The introduction of specialized insect biological control agents, although it contributes to biological pollution, appears to be an environmentally-sound solution to the much greater biological pollution caused by immigrant insects and introduced plants in Florida. Greater concern for insects as living things, or as integral parts of nature, coupled with increased understanding of how problem insects get into Florida, may foster a more even-handed approach to the reduction of biological pollution.

Key Words: Adventive species, biological pollution, immigrant species, insects and commerce, introduced species.

RESUMEN

Una proporción excesiva de especies foráneas (=no indígenas) en una comunidad ha sido denominada "polución biológica". Las proporciones de especies foráneas de peces, anfibios, reptiles, aves, y mamíferos en el sur de la Florida varían del 16 al 42%. En la Florida en su totalidad, la proporción de plantas foráneas es de alrededor del

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26%, mientras que la de insectos es de sólo el 8%. Casi todos los vertebrados han sido introducidos como animales de compañía, los cuales escaparon o fueron soltados en espacios naturales y se establecieron como poblaciones reproductivamente viables. Muy pocas especies llegaron como inmigrantes (= "por su propia voluntad"). Casi todas las plantas han sido introducidas, pero llegaron como inmigrantes o como contaminantes en importaciones de semillas. Sin embargo, sólo 42 especies de insectos (0.3%) han sido introducidos y todos como control biológico de plagas, incluyendo malas hierbas. El resto (aproximadamente 946 especies, ó 7.6%) llegó como inmigrantes desconocidos, algunos de ellos volando y muchos como contaminantes en cargamentos. La mayoría de los insectos perjudiciales para la agricultura, horticultura, construcciones humanas y el medio ambiente llegaron como "polizones" (contaminantes de, almacenados en, cargamentos, especialmente cargamentos de plantas). Parece ser que ningún insecto foráneo que cause problemas en la Florida fue introducido (deliberadamente).

La causa mayor de la llamada polución biológica es la demanda del público de animales de compañía y plantas ornamentales de origen extranjero, la irresponsabilidad del público manejando estos organismos, la avidez de los comerciantes en proporcionar dichos organismos a cambio de dinero y la reticencia de los gobiernos en cortar la avalancha de negocios lucrativos. Las causas del resto de la polución biológica estan fundamentadas casi en su totalidad en el desplazamiento en vuelo, por vía terrestre, a nado y en estructuras a la deriva desde los países vecinos caribeños, México, y Centro América. La introducción de insectos especializados en el control de plagas, aunque contribuya a la polución biológica, parece ser una solución medioambiental de peso al problema más grave de la polución biológica producida por los insectos y plantas llegados a la Florida como inmigrantes. Una preocupación mayor por los insectos, como entidades vivas, o como partes integrales de la naturaleza, emparejada con un incremento en el conocimiento sobre cómo los insectos problemáticos entran a la Florida, puede favorecer una estrategia más equilibrada para la reducción de la polución biológica.

Florida's flora and fauna are threatened by a burgeoning human population, approaching 14 million, with a growth rate triple that of the USA during the last decade. By the year 2020, this population could grow to 23 million. The Everglades are said to be dying due to water shortage and pollution. Florida Bay, at the tip of the peninsula, is threatened by enormous algal blooms said to be due to pollution from agricultural lands, and more than 40,000 ha of seagrasses and sponges are dead. Coral reefs are said to be dying from pollution and disturbance. Of 25 shrimp boats operating from Marathon in the early 1970s, there now are none. In the Tampa Bay area, wellfields have been over-pumped, drying up thousands of hectares of wetlands. In central Florida, lakes are said to be polluted with pesticides, causing, for example, a dramatic drop in the largemouth bass population and a 90% decline in the alligator population of Lake Apopka. On the east coast, from Fernandina Beach in the north to Miami Beach in the south, coastal erosion is said to be fueled by overpopulation: about $450 million have been spent pumping sand onto beaches since 1965 to replace the tons eroded by storms. Pollution in the Gulf of Mexico has made bacterial infection from eating raw oysters a frequent health risk. The conch population in the Caribbean has declined by 90% in the past 20 years, and edible marine fish populations on the east coast mirror this decline.

Millions of hectares of Florida no longer even remotely resemble a pristine state. They are now urban landscapes with buildings and roads and ornamental plants, or agricultural landscapes modified to support the human population, or salt marshes modified to suppress their natural mosquito populations so that humans will not be bitten. All of these changes have supplanted the natural plant and animal populations. All major agricultural crops, farm animals, and popular pet animals in Florida, from citrus to corn to cattle to cats, are introduced. Of all plants of foreign origin that are imported into the USA, 85% arrive through Miami International Airport. Miami also is the busiest US port for fish and wildlife. The root cause of what has been termed the "biological pollution" (McKnight 1993) of Florida is the public's desire for animals and plants of foreign origin, the public's environmental irresponsibility, dealers' ability to earn money by satisfying this desire, and governments' unwillingness to intervene substantially in this profitable commercial activity (Belleville 1994).

In southern Florida, especially, untrammeled whims of humans have introduced so many species of non-farm animals (mainly as "pets") that the native fauna is greatly diluted. Running wild in Dade and Broward Counties have been piranhas, walking catfish, blue tilapia ("introduced from Africa in 1961 by officials of the Game and Freshwater Fish Commission"), electric eels, little barbed Amazonian catfish that swim up [human] urinary tracts, and other fish ("23 exotic fish now breeding in the wild"), Cuban anoles, iguanas, Asian water monitors, caimans, boa constrictors, pythons, mambas ("people want the newest animals as pets"), red-whiskered bulbuls, monk parakeets, howler monkeys, gibbons, green African savannah monkeys, crab-eating macaques, and a herd of 300 buffalo (Belleville 1994). Nine years ago, the fauna of southern Florida included the following percentages of species introduced almost entirely by the pet trade: fishes (16%), amphibians (22%), reptiles (42%), mammals (23%) (Ewel 1986). The percentage of birds is obscured under a category called "free-flying exotics" but, with 16-17 species of parrots and many other species established, it may exceed the percentage of any of the other classes. Recent estimates compiled for all of Florida (US Congress 1993) suggest the percentages of established adventive vertebrate species exceed 20% for most groups. Many such "pet" animals escaped from their owners, or were released deliberately, into the wild. Animals shipped from Florida also have caused problems. For example, red-eared turtles are shipped to France, Belgium, the Netherlands and Germany; over 500,000 individuals are shipped to France alone per year. Some inevitably escaped into the wild where they displaced native turtles (Simons 1994).

Importers of non-crop plants (mainly as "ornamentals") likewise have contributed to dilution of the native flora. Among the worst weeds (Exotic Pest Plant Council 1993) are punk trees, introduced to Florida "to drain wetlands"; water hyacinth, "imported for its pretty, orchidlike blossom"; hydrilla, "a frilly little plant in aquariums"; and Australian pine, "introduced as an ornamental" (Belleville 1994); others include Brazilian pepper, kudzu vine, and cogon grass, all introduced (deliberately). The USDA and Fairchild Botanical Gardens had active programs to introduce tens of thousands of plants of foreign origin for no reason essential to human existence. At present, about 27% of the total established flora of Florida is comprised of adventive species (Table 1). Waiting in the wings, some 25,000 introduced plant species are grown in cultivation, but are not **yet** established in nature (Table 1). Florida is not only a beneficiary of plants of foreign origin, but a donor, and it also donates pest insects infesting ornamental plants (Miller 1994).

The purpose of this introduction is to show what problems adventive species of insects cause in Florida (also see US Congress 1993). These species are placed into a framework that categorizes them to show which ones were **introduced**, and estimate how many arrived without invitation, i.e., were **immigrants**. We also pose some philosophical questions about introductions of insects and other organisms to Florida.

TABLE 1. A COMPARISON OF THE FLORIDA FLORA AND FAUNA

Type	Plants	Insects
Indigenous species	2,525[a]	11,512[c]
Adventive species		
Species immigrant to Florida and established in nature	0[f]	946[c]
Species introduced to Florida and established in nature	925[a,f]	42[d]
Species now cultivated, but not established in nature	25,000[b]	5[e]

[a]after Ward (1989), [b]after comments by David Hall and Thomas Sheehan, [c]estimates explained in Frank & McCoy (1995), [d]biological control agents, after Frank & McCoy (1993), [e]house crickets and mealworms as fishbait, honey bees, silkworms, and a mantis, [f]some of the plants reported by Ward (1989) as "introduced" may, in fact, be immigrants, because it is scarcely conceivable that some of the weeds among them were introduced deliberately, and their seeds may have arrived on the wind, in sea-drift, or as contaminants of shipments of other seeds or materials.

THE CURRENT STATUS OF ADVENTIVE INSECT SPECIES IN FLORIDA

Nomenclature

A distinction is made in this paper between **immigration** and **introduction**, following Frank & McCoy (1990). **Immigrants** arrive of their own volition, even if as stowaways in cargoes, and have **no** permit for their entry into Florida. The word **introduced** is restricted to purposely-introduced species, following Zimmerman (1948). A Florida permit (DPI-FDACS) is now required for **introduction** of **any** insect species into Florida, and in many examples a federal permit (USDA-APHIS-PPQ or USDA-APHIS-VS or USPHS-CDC) also is required. **Adventive** species (elsewhere called non-indigenous species) are those that immigrated together with those that were introduced.

Recognition of Adventive Species

Assessment of adventive insect species in Florida is complicated by a very imperfect knowledge of indigenous species (see Frank & McCoy 1995). There is no baseline information on insects from the time of the rediscovery of the Americas by Columbus, nor from the time of the American revolution. Only for a few (mainly pests) is there information from even 100 years ago, and some are not yet recorded at all. There are now manuals on the Florida species of a few insect families. An enormous amount of taxonomic research still is required, especially on species that are not pests. This research is progressing at a snail's pace because it has little popular appeal, and public funds to support it are virtually unavailable.

The extreme south of Florida presents a special problem as to which species are adventive. Many West Indian insects inhabit the Florida Keys and adjacent mainland. The major part of the range of these species is in Cuba or other islands, and they also inhabit a small part of Florida. Lack of baseline data for some species from 20 years ago, much less 200 years ago, makes it impossible to state how long they have been in Florida. Some species undoubtedly become extinct in Florida from time to time, and then recolonize by flight and winds from the south. Six of them are butterflies: *Chlorostrymon maesites* Herrich-Schaeffer, *Eunica tatila* Herrich-Schaeffer, *Strymon acis* Drury, *Eumaeus atala* Poey, *Heraclides aristodemus* (Esper), and *Anaea* *troglodyta* F. Other insect species are so poorly studied that when they are reported for the first time from Monroe County or Dade County, they are recorded as immigrants simply because there is no earlier information. However, the six butterfly species are listed among Florida's rare and endangered invertebrate animals. There is unequal treatment under the law because butterflies have popular appeal, so there is more information about them. Inadequate knowledge of the insect fauna of Cuba and the Bahamas compounds the problem. Florida-based entomologists were discouraged for years from working in Cuba for political reasons.

Records of Adventive Species

Systematic knowledge about Florida's insect fauna is woefully inadequate (see Habeck 1987), because the almost exclusive demand from the public has been on methods for controlling pest species. No agency of the Florida government has a program providing grants for taxonomic research on non-pest species of insects. Although these insects are considered to be wildlife by the US Fish and Wildlife Service (USFWS), they are not considered to be wildlife by the Florida Game and Fresh Water Fish Commission (FGFWFC). Consequently, the Non-Game Wildlife Program of FGFWFC rarely makes funds available for research on them. Professional entomologists were hired in Florida almost entirely to solve problems caused by pest insects. The Florida Department of Agriculture and Consumer Services (FDACS) responded to the need for knowledge on insect fauna in general by housing the Florida State Collection of Arthropods in Gainesville, by paying publication costs for taxonomic work on non-pest species (should someone be willing to write them), and by encouraging donation of specimens to the collection. The Institute of Food and Agricultural Sciences of the University of Florida pays publication costs for work by students and employees on non-pest species, but does not encourage such research.

As a consequence of the emphasis on pest insects, families containing pests [e.g., Culicidae (mosquitoes) and Diaspididae (armored scale insects)] are well known, but families containing mostly innocuous insects are not. The sole exception is the group of families (Nymphalidae, Papilionidae, Pieridae, etc.) called butterflies. Therefore, there is no thorough catalog of the insect fauna of Florida. Although many hundreds of immigrant species now exist in Florida, they are yet a fairly small percentage (under 9%) of the total number of species (Table 1). For example, only four of the 78 mosquito species are immigrants (Frank & McCoy 1995). The proportion is likely to be higher among plant-feeding insects than among non-plant-feeding insects, because many pests of plants have immigrated with imported shipments of plants. The proportion of introduced species is less than half of 1% (Table 1).

Extremely few populations of insect species are monitored routinely in several Florida localities: almost the sole exceptions are some mosquitoes. Most populations are noticed only when their numbers are very high, and cause damage to ornamental plants, crop plants, structures, livestock, and other human possessions. The task of annual monitoring of more than 12,500 insect species (Frank & McCoy 1995) is vastly beyond current capabilities, so there is virtually no information on most adventive insects in Florida.

Recognition that many of the major pests of North American crops were adventive, and probably had immigrated with infested shipments of plants, led to the Federal Plant Quarantine Act of 1912 (Sailer 1978). The act was designed to bar the importation of cargoes infested with plant-feeding insects, through inspection at ports. Much harm had already been caused to agriculture by such immigrant pests. Implementation of the law, however, merely slowed the establishment of immigrant insect species, and did not prevent it (Sailer 1978). USDA-APHIS inspectors at US ports and airports in fiscal year 1980 intercepted over 18,000 infested shipments (Frank & McCoy 1992).

Unlike the northern parts of the USA, Florida contends not only with infested shipments, but also with flight of insects from the West Indies. Assessment of the literature showed 271 immigrant insect species reported for Florida for the first time between 1971 and 1991 (Frank & McCoy 1992). These were living in Florida when found, and the information gives a rough measure of the current rate of establishment of immigrant species. Relatively few insect species are introduced under permit (Frank & McCoy 1993, 1994).

Major Pathways of Arrival of Adventive Species

Immigrant species: fly-ins. Florida's northern and western borders are permeable to flying and walking insects. Many of Florida's insect species (including pests) are shared with neighboring states for this reason. A familiar example is the love bug (*Plecia nearctica* Hardy). This is a Mexican and Central American species which extended its range to include the Gulf Coast of the USA. Moving into Florida from Alabama in 1949, its population spread to southern Florida in 1975 (Buschman 1976). A large proportion of the insect species of southern Florida arrived by flight, perhaps assisted by winds, from the West Indies, the Bahamas, and the Yucatan peninsula of Mexico. Even wingless species may have arrived by rafting on floating driftwood. Arrival of additional species by flight will continue indefinitely. An aphid which may arrive soon from Cuba (it colonized Cuba from Central America), is *Toxoptera citricida* (Kirkaldy), a vector of tristeza disease of citrus. There is no way of preventing such immigration, although some immigrants from the south, if detected soon after they arrive, may be eradicated by use of chemicals.

Immigrant species: stowaways. More than 25,000 adventive species of plants now grow in Florida (Table 1). Every imported shipment of plants offers opportunity to plant-feeding insects to immigrate as stowaways. Despite the efforts of shippers and inspectors, such plant-feeding insects continue to immigrate. These insects tend to be the most important pests of the introduced plants, but some of them turn their attention to related, indigenous plants. Thousands of shipments are discovered every year to contain insect stowaways, but only a tiny percentage of shipments is inspected at ports and airports. Furthermore, Miami International Airport receives 85% of all shipments of plants to the USA. These, along with shipments of other kinds of cargoes that arrive by air, sea, and land, have been, and continue to be, the main method of immigration of Florida's most important adventive pest insects (Frank & McCoy 1992).

Introduced species: commerce in insects. There has been enormous commerce in introduced plants, and some of these plants have become weeds. In contrast, there has been very little commerce in insects introduced for purposes other than biological control, except for European honey bees (*Apis mellifera* L.) and, to a trivial extent, oriental silkworms (*Bombyx mori* L.). Much more recently, other insects, including a Chinese mantis (*Tenodera aridifolia* Stoll), a Madagascan cockroach (*Gromphadorhina* sp.), a European cricket (*Acheta domesticus* (L.)), and a giant mealworm of unknown origin (*Zophobas* sp.), have been imported and sold to the public as pets, or for educational purposes, or as fishing bait; their owners sometimes release them into the wild, or they escape (Frank & McCoy 1994). Some adventive butterflies are imported for living displays by commercial butterfly zoos, but are not intended for release into the wild (Frank & McCoy 1994). There is no evidence that any of these species have established populations in nature in Florida or have caused environmental harm. To reduce future risk from this avenue, such importations are now allowed only after review and under permit from the Division of Plant Industry, FDACS (Florida Administrative Code 1993).

Twenty-one insect species adventive to Florida have been imported commercially as biological control agents since 1980. At least four of these already have established populations in Florida, and some others are indigenous to other parts of the USA (Frank & McCoy 1993, 1994). None of these species has been reported to cause environmental damage. Importations of biological control agents from abroad are allowed only after Federal review and under Federal permit. Florida, virtually alone among the States, now requires its own review and additional permit from the Division of Plant Industry, FDACS (Florida Administrative Code 1993); furthermore, Florida requires this permit even for importations from other parts of the USA. It is to the advantage of the companies selling biological control agents that these species **do not** establish populations in Florida, or at least are not able to sustain large populations, because such populations could eliminate or reduce repeated sales.

Introduced species: importations by government and universities for biological control of pests. These are non-commercial introductions of species which initially are imported under permit into secure quarantine laboratories. If, after testing, they prove to be specific natural enemies of targeted pest species, then a second round of permits is required before their progeny may be released into nature. Targets are pest insects and weeds, and most of these are immigrants (Frank & McCoy 1993). This is the most tightly regulated of all forms of introductions of animals: insects imported into Florida from abroad require Federal (USDA) and State (DPI) permits for importation to quarantine, and Federal and State permits for release into the wild. They may also need documentation of importation as wildlife from the USFWS, and may need various export permits from their countries of origin (depending upon the laws of the country in question).

Despite all the testing and paperwork, most introduced biological control agents do not establish populations. Records show that 151 insect species have been released in Florida as biological control agents, 139 of them against pest insects and 12 against weeds (Frank & McCoy 1993). Among those that became established (34 against insects, 8 against weeds), some proved highly beneficial. Examples are the minute wasps *Amitus hesperidum* Silvestri and *Encarsia opulenta* (Silvestri) that now control citrus blackfly, and the flea beetle *Agasicles hygrophila* Selman & Vogt that now controls alligatorweed. Although regulations governing introduction of insect biological control agents were less stringent 50 years ago, none of the 42 introduced species has been shown to have detrimental effects on the environment.

Problems Caused by Adventive Species

Immigrant insect species annually cause hundreds of millions of dollars in damage to agriculture (including livestock and forestry), horticulture, and structures in Florida. Research into these problems is supported by public and private funds, but the system is being swamped by the high arrival rate of immigrant pests. The following problems, especially notable because of their occurrences on public lands, are the principal ones that we can identify. The only realistic hope for a long-term solution to any of these problems is through introduction of biological control agents (Tschinkel 1993, Frank & Thomas 1994).

Tillandsia bromeliads. Metamasius callizona (Chevrolat) is a weevil native to Mexico and Central America. In 1989 it was discovered on introduced bromeliads in a nursery in Broward County. Surveys were made, and weevils were found on public lands throughout Broward County and in Dade and Palm Beach Counties, and on private lands in Lee County. Populations of the indigenous bromeliad *Tillandsia utriculata*, which is protected under State law, have been decimated in Broward County parks. The weevil also kills the indigenous *Tillandsia paucifolia* and *Tillandsia fasciculata*, and is too widespread to eradicate by the use of chemicals. It seems inevitable that populations of these protected plants will decline drastically throughout their range in Florida (Frank & Thomas 1994), and they are candidates for listing as endangered.

Introduced Ficus spp. Over 60 exotic *Ficus* (fig) species have been introduced into southern Florida as ornamentals. It was thought that none of these species would set viable seed because each is pollinated only by its own species of agaonid wasp, and the wasps were not introduced. But, *Ficus altissima* Blume, *F. benghalensis* L., and *F. microcarpa* L., are now weeds because they are pollinated routinely by immigrant agaonid wasps. Fertile seeds of these enormous trees now germinate in Dade and Monroe counties. Seedlings sprout in public and private lands and on structures, such as highway bridges, where they pose a maintenance problem, because they can destroy the structures as they grow. They are invasive on public lands. There is evidence that the pollinating wasps of *Ficus microcarpa* arrived in seeds brought from Hawaii, and there is concern that fruits (and thus seeds) of the other two fig species are being spread by introduced parrots (Nadel et al. 1992).

Endangered cacti. *Cactoblastis cactorum* Bergroth is a moth, native to South America, whose larvae feed on *Opuntia* cacti. Introduced into Australia in 1925, it saved 12 million acres of pasture land that had been rendered useless by infestation with two species of *Opuntia* unwisely imported from the Gulf of Mexico coast. Between 1957 and 1970, it was introduced into Nevis, Montserrat, Antigua, and Grand Cayman, where *Opuntia* spp. were weeds. From those islands it spread to Puerto Rico, Haiti, the Dominican Republic, and the Bahamas, and in 1989, was found in the Florida Keys (Habeck & Bennett 1990). Unfortunately, in the Florida Keys, it places the rare cacti *Opuntia spinosissima* Martyn (Mill.) and *Opuntia triacantha* (Willdenow) at risk. *Cactoblastis* probably arrived in Florida as a contaminant of *Opuntia* imported as ornamental plants. Inter-island flight or stowing away aboard boats are less likely means of arrival. Deliberate importation as a biological control agent for *Opuntia* cacti, by some member of the public, is still less likely.

Endangered morning glories. Florida's endangered species of morning glories are *Ipomoea microdactyla* (Grisebach) and *Ipomoea tenuissima* Choisy. Sweetpotato (*Ipomoea batatas* Lamarck) is a relative. These plants face a new threat: the tortoise beetle *Chelymorpha cribraria* (F.) This leaf-feeding beetle was discovered in Broward County in 1993, and its range had spread to Dade County's Matheson Hammock Park by March 1994 (Thomas 1994). The beetle is native to South America and the West Indies. Importation of infested sweetpotato is a likely means of arrival.

Fire ants. *Solenopsis invicta* Buren, inaptly termed "the red imported fire ant," arrived in the southern USA about 1940 as an immigrant from South America. Gradually it spread throughout the south, in part by flight, and in part as a contaminant of cargoes. In agricultural ecosystems it inflicts important mortality on such pests as sugarcane borer, boll weevil, and horn fly, but also destroys indigenous natural enemies of these and other pests. It has displaced populations of native ants in disturbed habitats and it kills nestling birds, but its effect on undisturbed public lands may be much less than on disturbed lands (Tschinkel 1993).

Conflicts Caused by Adventive Species

The means of arrival of immigrant species often is obscure. By definition they were not introduced under permit, so there are no records of introduction. An example is *Cactoblastis cactorum*. This moth was introduced to Australia deliberately, to combat *Opuntia* cacti. These plants had been introduced to Australia deliberately for horticultural reasons, but became invasive and caused great losses to agricultural interests. Agriculture was in conflict with horticulture, but public interests were on the side of agriculture. Introduction of the moth to Australia, and its successful control of *Opuntia*, were viewed as highly beneficial.

Cactoblastis was introduced into Nevis, Montserrat, Antigua, and Grand Cayman to suppress *Opuntia* on agricultural lands, and the introductions were requested by the governments of those islands. *Cactoblastis* was not introduced into Puerto Rico, Haiti, the Dominican Republic, or the Bahamas by their governments. Either the moth was smuggled to these islands by private agricultural interests to combat *Opuntia* species that were viewed as weeds, or it flew there from the other islands or hitchhiked on boats.

The situation is more complex in Florida. Horticultural interests have imported *Opuntia* cacti into Florida as ornamental plants, and some of these imported plants are known to have been infested with *Cactoblastis*; this is by far the most likely means of arrival. There are private agricultural interests that would view introduction of *Cactoblastis* as beneficial to suppress *Opuntia* on rangelands, though its discovery in the Florida Keys, which are not noted for agriculture, suggests that this was not the means of arrival. But, in Florida, there are endangered *Opuntia* species. The interests of agriculture, horticulture, and conservation are here in conflict. Boat traffic between the Florida Keys and other islands gives adult moths a good possibility of hitchhiking. There is a minor possibility that adult moths flew directly from Cuba, perhaps aided by winds.

Some Philosophical Concerns About Insects and Insect Introduction in Florida

Although species of exotic vertebrates and plants have, for the most part, been **introduced** to Florida deliberately, adventive species of insects are predominantly **immigrants** (i.e., not deliberately introduced; see Frank & McCoy 1990 for a discussion of these terms; also see Frank & McCoy 1992, 1993, 1994). The introduced vertebrates and plants were brought to Florida because they were thought to possess desirable properties, and only later did they prove to be invasive and potentially detrimental to the native flora and fauna. The introduced insects also were brought to Florida because they were thought to possess desirable properties, principally in controlling pests. It is not clear that any of the insect species introduced to Florida for pest control have been detrimental to the native biota, although the potential for harm clearly is present (see Simberloff 1992, Simberloff & Stiling 1993). The potential for harm to rare insects outside the crop environment is an especially important, although underappreciated, consideration of classical biological control programs (Samways 1988, 1994).

The need to integrate conservation and pest control concerns raises some interesting philosophical—as well as practical—questions. The first has to do with insect conservation: Is too little attention paid to insect conservation (see New 1984, Samways

1994)? In Florida, the official lists of endangered and potentially endangered animal and plant (Wood 1993) taxa include 17 of fish (includes species, subspecies, and populations), 6 of amphibians, 27 of reptiles, 45 of birds, 43 of mammals, and 566 of plants. The lists also contain 85 invertebrate taxa, of which 47 are insects. Seven orders are represented among the listed insect taxa: Ephemeroptera (2 taxa), Odonata (4), Orthoptera (4), Coleoptera (19), Trichoptera (6), Lepidoptera (8), and Diptera (4). Within the two best-represented orders, 6 of the 8 lepidopteran taxa are butterflies, and 15 of the 19 coleopteran taxa are scarabs. One butterfly, Schaus' swallowtail, is listed as endangered by both the USFWS and the FGFWFC; the other 46 insect taxa are listed as C2 by USFWS, but are not listed at all by FGFWFC. The C2 listing offers no federal protection, and means only that USFWS encourages consideration of such taxa in environmental planning. Furthermore, the document created to allow governmental agencies in Florida to set conservation priorities in a reasonable way (Millsap et al. 1990) keys only on "fish and wildlife," and, thus, does not deal with invertebrates or plants. By implication, the omission of invertebrates, coupled with their relatively-poor representation in the official lists, suggests that persons who might be interested in studying rare invertebrates probably are not likely to obtain funding from the agencies who employ this document. Although the USFWS insists that insects are "wildlife," the FGFWFC apparently has not subscribed to this inclusive definition in the granting of funds through its Non-Game Wildlife Program (with the exception of Schaus' swallowtail). The advice to persons interested in insect conservation often is to apply to an agricultural agency for funding, even if the kinds of insects those persons wish to study have nothing to do with agriculture. Finally, the attempt to set conservation priorities in a reasonable, comparative way (Millsap et al. 1990), and thereby to avoid use of perception, politics, and other such criteria which typically affect governmental lists of taxa at risk (see McCoy & Mushinsky 1992), succeeds, as much as it does, only for vertebrates. Among insects, the few conservation efforts that are mounted are likely to be directed at the showy, popular taxa, such as butterflies and beetles (see Pyle et al. 1981, Samways 1994), rather than at the bland ("ugly" in some minds), obscure taxa, despite the fact that such taxa may be equally, or even more, threatened (see Samways 1994).

So, a case can be made that indeed too little attention is paid to insect conservation. We suggest that it is important at least to recognize the possibility that a very large and diverse group of organisms is being neglected. Insects currently suffer from a poor public image, although they have not always done so (Frank & McCoy 1991, Samways 1994). Unfortunately, some popular philosophical theories about nature reinforce this poor image. For instance, individualistic theories embraced by many animal-rights activists (e.g., Regan 1983, Singer 1985), apart from their failure to attach increased moral status to endangered taxa, paternalistically focus attention on creatures which are most like humans (see des Jardins 1993). So-called holistic philosophical theories about nature offer an alternative to individualistic theories—and to biocentric theories (e.g., Taylor 1986), as well (see des Jardins 1993). The commonly employed philosophical and ecological bases for these holistic theories seem to be weak, however (Peters 1991, Shrader-Frechette & McCoy 1993). Because of their numbers and diversity—and even their utilitarian values—insects are likely to fare well under a more holistic perspective of nature. And if so, then it follows that to employ this more holistic perspective, we must better understand the ecological roles insects play. A first step toward increased understanding in Florida is characterization of the habitats of very many more of the taxa indigenous to the state, especially those that are precinctive (Frank & McCoy 1995), a process that is well under way in other places, such as the Amazonian rain forest (T. Erwin pers. comm.).

A second philosophical and practical question involves movements of organisms. The question is: Are the risks of introductions of certain kinds of organisms, namely classical biological control agents, scrutinized too closely, relative to those of other kinds of organisms? To address the question, we must provide a little history.

Importers of insects have for years had to follow federal regulations required by USDA-APHIS-PPQ, USDA-APHIS-VS, and USPHS-CDC. These regulations were designed to ensure that insects imported into the USA should not become pests; that is, they were not likely to be phytophagous on commercially-important plants ("plant pests"), or parasites and/or vectors of diseases of farm animals ("animal pests"), or parasites and/or vectors of diseases of humans ("vectors"). By extension, the regulations were applied to phytophagous insects that were actual or potential biological control agents of weeds, so that such insects could be imported only to approved quarantine facilities, until further approval for release were issued. By further extension, under nebulous authority, the regulations also were applied to entomophagous insects imported for biological control purposes. We shall place the insects discussed in this paragraph in "category A."

The federal regulations applied to insects in category A never applied to many other insects that at least had the potential to become pests. Among these other insects are termites, cockroaches, pests of stored products (e.g., mealworms and crickets imported as fish bait), honey bees, silkworms, insects imported for "educational purposes" (e.g., certain mantids), and insects and other arthropods imported as "pets" (e.g., certain scorpions and tarantulas). Insects, such as exotic butterflies imported by hobbyists or insect zoos, might or might not have been considered "plant pests," but were not required to be held in quarantine facilities regardless. While agricultural inspectors at land-, sea-, and airports examined cargoes for "plant pests" and "animal pests," they more or less left other living arthropods alone. Further, agricultural inspectors had no jurisdiction over the business of USPHS-CDC—which did not have its own inspectors—so they were not required to report discovery of "vectors," such as mosquito larvae, among shipments of plants. Still further, although agricultural inspectors could deny entry to declared biological control agents without permit, they did not have jurisdiction over entomophagous insects, and were not required to report these either, so entomophagous insects could be imported by the public. In brief, there was little or nothing to prevent members of the public from importing all kinds of entomophagous and other insects—so long as they were not obvious "plant pests" or "animal pests"—and nothing to prevent these insects from being released into the environment. Put simply, a wide variety of living insects could be imported legally and released into the environment. Agriculture and horticulture were protected, which was the stated purpose of the law, but the natural environment was largely unprotected. We shall place the insects discussed in this paragraph in "category B."

Later, EPA was empowered to regulate entry of biological control agents. By federal inter-agency agreement, it was decided that USDA-APHIS was doing a good job of regulating entry of insect biological control agents, and the EPA had no need to duplicate the effort. But, the emphasis still was on regulation of insects in category A. The insects in category B, that had been ignored by USDA-APHIS, were now being ignored by EPA.

The Florida legislature, in 1993, finally saw that all sorts of insects and other terrestrial arthropods were entering Florida under various guises, not only from abroad, but also from other states of the USA. It decided that **all** living insects and other terrestrial arthropods that anyone wanted to import should be subject to evaluation and permitting by DPI-FDACS. The law that it enacted was, arguably, the first sensible attempt at regulating importation of living organisms in the country. In fact, it makes the federal laws unnecessary and redundant, as far as importations into Florida are concerned. The Florida law should serve as a model for a revised federal law. Only if the federal law becomes as stringent as the Florida law, and covers inter-state shipment, should the Florida law be repealed.

Later still, USFWS, which has no inter-agency agreement with USDA-APHIS, decided that insects are wildlife and importers/exporters of insects must follow its wildlife regulations and the wildlife regulations that it attributes to countries of origin. Thus, for example, anyone collecting insects in Mexico has to buy a Mexican hunting permit (for $750) and hire a Mexican hunting guide, according to USFWS regulations. Such permits are difficult—nearly impossible—to obtain, and so all insects exported from Mexico, dead or alive, are currently illegal in the eyes of USFWS. Tens of millions of insect specimens in national, state, and private collections technically are illegal contraband, because they are not accompanied by wildlife permits. USFWS does not recognize Mexican collecting/export permits for insects issued by Mexican agricultural/scientific authorities, which are much easier to obtain. Although USFWS is rightly attempting to restrict trade in insect specimens belonging to endangered species (mainly butterflies), it is inadvertently causing a severe hindrance to biological control. This problem could be solved by federal inter-agency agreement.

Based on our historical account, we conclude that the risks of introduction of biological control agents are scrutinized much more closely than those of other kinds of insects. We would not suggest that as a consequence of this uneven treatment, monitoring of importation of biological control agents should be slackened. Indeed, there is need for classical biological control to become more predictive (see Samways 1994). Rather, we would suggest that monitoring of the importation of other kinds of insects needs to be tightened, if the realized and potential threat of “biological pollution” by insects is to be lessened. To lessen the threat, we submit the following four proposals. First, legal (under permit) and illegal (without permit) importation of “pet” insects and other terrestrial arthropods should cease. Penalties for attempted illegal importation will have to be made more obvious and more severe. Second, insects imported for educational and research purposes (by universities, schools, zoos, and other organizations) should be held under conditions as secure as those now required for initial importation of biological control agents. Third, importation of “ornamental” plants should cease, unless importations are limited to seed—to restrict hitchhiking insect pests—or unless all incoming shipments are fumigated with chemicals shown to have ovicidal activity or dipped in chemicals with ovicidal activity. Fourth, all incoming shipments containing wood or other vegetable matter, even if only as packing crates, should be fumigated with chemicals shown to have ovicidal activity. Importers of insects or vegetable matter will have to pay the costs of any necessary secure facilities or required chemical treatment. All ships and boats arriving at Florida docks will have to be fumigated at owners’ expense. All road vehicles will have to be stopped at Florida’s borders and the drivers cautioned about potential searches, and fumigation of plant materials. If these restrictions cannot be implemented, because of political and economic pressure, then importers should pay into a fund which would provide research costs for the biological control of organisms that become established in nature.

CONCLUSIONS

Many biologists still fail to comprehend the means of arrival of adventive (= “non-indigenous”) organisms in Florida, and in the USA in general. It may be that almost all adventive vertebrates and plants are introduced. But, by following an assumption that adventive insects likewise are introduced, they confuse purposeful introduction with all other means of arrival. We distinguish these other means of arrival as **immigration**, which we consider to include all the undocumented modes of arrival, including flight, walking, swimming, rafting, and hitchhiking in cargoes. It is **immigrant** species which form 95.7% of the adventive insects in Florida (Frank & McCoy 1995) — and some of them are important pests. The **introduced** species in Florida, in contrast, were imported and released under permit because they are potentially beneficial—all of them are biological control agents of pests. None of them has been implicated in any kind of environmental damage. We are concerned that well-meaning but uninformed biologists should not label "introduced" (= all non-indigenous; their definition) insects as necessarily a bad thing for the environment—when, in fact insects **introduced** (our definition) by humans may be the least risky way to save the environment from damage caused by other organisms, purposefully or inadvertently, brought to Florida by humans.

THIS SYMPOSIUM

We have suggested that, in order to deal with biological pollution in a more even-handed way, greater attention needs to be paid to documentation of Florida's insect fauna and to philosophical and practical questions involved with insect introduction. The contributions to this symposium address these two subjects. J. H. Frank & E. D. McCoy (1995) offer, for the first time, estimates of the current size of the Florida insect fauna, the proportion of indigenous and adventive species and, within these categories, the proportion of precinctive, indigenous but not precinctive, and immigrant species. They use information from various experts coupled with knowledge from an earlier paper on number of introduced species, to derive these estimates. They then compare their estimates with similar ones derived for the insect fauna of Hawaii. Although Hawaii's immigrant insect problem is much worse than Florida's, Frank & McCoy (1995) find no reason to be complacent, because Florida's immigrant insect problem may be much worse than those of most of the other contiguous states.

Plants introduced for ornamentation and insects introduced for purposes other than biological control raise important questions about the efficacy of biological introductions in general. For these kinds of organisms, especially, the risks to the public could be great enough to outweigh any benefits of introduction that might accrue. Substantial attention should be paid to the potential risks of such introductions. D. Cathcart discusses the potential benefits of importing bromeliads: aesthetics; research on systematics, physiology, and culture methods; preservation of gene pools; and, perhaps, production of bromeliads to restock areas in their native lands where they have become extirpated or endangered. He also discusses the precautions taken by his firm to ensure that insects do not hitchhike into Florida on bromeliads. R. Boender discusses the potential benefits of importing butterflies, and derives a list very similar to Cathcart's: entertainment, education, research on production methods, production of living specimens for use by researchers, preservation of gene pools and, perhaps, production of butterflies to restock areas in their native lands where they have become extirpated or endangered. He also discusses the precautions taken by his butterfly farm and exhibition to ensure that butterflies do not escape and become established "plant pests."

Insects introduced as biological control agents have contributed some conspicuous successes in the struggle to reduce the effect of invasive adventive species in Florida. T. D. Center and co-workers illustrate the use of biological control to solve problems caused on public lands—including waterways—by introduced and immigrant species.

Problem species on public lands mainly are plants, but to a lesser extent, also include insects. Center and co-workers reiterate the important point that even though some members of the public may see classical biological control as contributing yet more adventive species to already burdensome numbers, classical biological control is an environmentally sound solution to the problem caused by some introduced and immigrant species.

Insect introduction for the purpose of biological control has a long history of government regulation in Florida. M. C. Thomas reflects the concerns of FDACS-DPI about immigrant and introduced insects. He points out that state laws now require importation permits for **all** arthropods and molluscs (no longer just for "plant pests" and biological control agents) from anywhere outside Florida. He warns of the significant potential danger to the environment from the kinds of arthropods and molluscs that the pet trade has been importing.

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THE IMPORTANCE OF MAINTAINING BROMELIAD IMPORTS

D. J. CATHCART
Tropiflora, 3530 Tallevast Road, Sarasota, FL 34243, USA

ABSTRACT

Exotic bromeliads are important to horticulture in Florida. Several hundred bromeliad species from eight common and over 40 obscure genera have been imported into Florida to fuel an industry of horticulture and scientific enquiry. Recent moves aimed at restricting the importation of exotic fauna and flora, including bromeliads, could be detrimental to an important industry. This information is presented to argue for the economic importance of bromeliads, their low incidence of pest infestation and lack of any threat to native species through intentional or unintentional release of imported species to the wild. Additional benefits are gained from the cultivation and ultimate preservation of endangered taxa.

Key Words: Bromeliaceae, insects, introductions, exotic species, Florida

RESUMEN

Las bromelias exóticas son parte importante de la horticultura en la Florida. Varios cientos de especies de bromelias correspondientes a 8 géneros comunes y más de 40 no comunes han sido importadas a la Florida con el propósito de incrementar la industria de la horticultura y de satisfacer las necesidades de la investigación científica. Las recientes medidas de restricción a la importación de flora y fauna exóticas, incluyendo bromelias, podrían actuar en detrimento de tal actividad. La presente información sustenta el interés económico de las bromelias, su baja incidencia de infestación, y la ausencia de peligro alguno para las especies nativas, motivado por la liberación intencional o accidental de especies importadas. Beneficios adicionales podrían obtenerse mediante el cultivo y la preservación de los grupos en peligro de extinción.

The first exotic bromeliads to be introduced to horticulture in Florida were imported from Europe at the beginning of the last century. Although the USA became the leader in bromeliad sciences, Europe never relinquished its hold on the U.S. market. Today, millions of seedlings and tens of thousands of finished plants are imported annually into the USA from Belgium and Holland alone. In Florida, over a dozen large nurseries and many smaller ones devote themselves to bromeliad production. Ornamental bromeliads have become a commercial crop worth an estimated $20 million per year to Florida horticulture. Several meristem laboratories in Florida have begun production of patented and non-patented bromeliad varieties, but most bromeliad nurseries in Florida and, indeed, the entire USA depend partly or wholly on imported meristems, seedlings or cuttings for their growing-on stock.

BROMELIADS AND THEIR CULTIVATION

Bromeliaceae are tropical and subtropical herbs, native, with a single exception, to the New World. Over 2,000 species belong to three subfamilies (Pitcairnioideae, Tillandsioideae and Bromelioideae) with approximately 50 genera. In general, bromeliads form rosette-shaped whorls of parallel-veined leaves and produce perfect, 3-petaled flowers. Leaves are covered with trichomes or peltate scales which enable these plants to adapt to various harsh growing condition. Bromeliads may be terrestrials, facultative epiphytes, or obligate epiphytes, and exhibit great diversity among family members: compare *Ananas comosus* (L.) (pineapple) with *Tillandsia usneoides* (L.) (Spanish moss).

A Brief History

Exotic bromeliads have been a factor in the horticultural world since the 1500s. On his second voyage in 1493, Columbus was introduced to *Ananas comosus* by the Carib Indians on Guadeloupe. This plant had been a part of pre-Columbian culture for untold years. By the end of the 1700s, the subfamilies of bromeliads had been described. Early plant explorers prized bromeliads for their unusual form and beauty. By the late 1700s and early 1800s, the search was on in earnest for new species, introducing hundreds of species to cultivation in Europe by the turn of the twentieth century.

Although Florida has 17 native species of bromeliads, representing three genera in the subfamily Tillandsioideae, these were never horticulturally important. The first exotic bromeliads to be introduced to Florida horticulture were imported from Europe at the beginning of the last century. Florida's pineapple industry, begun in the 19th century, peaked in the 1930s, and it is now very small. Changing weather conditions eventually made it unprofitable.

Importance to Agriculture and Horticulture

Historically, bromeliads have had limited agricultural use. Several bromeliad species produce commercially important fibers. Bromelain, an enzyme produced by *Ananas comosus* fruits in defense against insect larvae (Benzing 1980), is becoming important in the chemical and pharmaceutical industries. A second enzyme, hemisphericin, produced by *Bromelia*, may become important (Gutierrez et al. 1993). As a food source, bromeliads provide a few species with edible stems, flowers, roots and fruits, the most notable of which is *Ananas comosus*. Now, more than ever before, bromeliads hold the promise of a bright future in the horticultural industry.

Florida's Commercial Production of Ornamental Bromeliads

Commercial bromeliad production in Florida is now centered on the production of ornamental varieties. Large and modern facilities produce millions of finished bromeliads from domestic and imported seed, meristems, cuttings and pre-finished material. Most revenues are generated in the market for bromeliad hybrids for interiorscape and flowering potted-plants, with only 8 genera and a few dozen species dominating production.

A much smaller but still important part of the bromeliad market lies in the production of bromeliads for use as novelties. This includes various species grown especially for use in dish gardens, for mounting on decorative wood and as 'tourist novelties', such as small *Tillandsia* plants on magnets and sea shells.

A growing sector of the industry is producing bromeliads as landscape plants. South and central Florida, and the warmer parts of the sun belt are well suited to exploit this potential in bromeliads. Several Florida nurseries now specialize in landscape bromeliad production.

Many people across the country and the world have collections of bromeliads. To satisfy their needs, several smaller Florida nurseries specialize in the production of a wide array of species, hybrids and cultivars.

International Trade in Bromeliads

Although the production of bromeliads in the USA (with the exception of pineapples) is centered in Florida, our state by no means has a lock on the industry. California is second to Florida in bromeliad production, and Hawaii is now entering the market place.

Just as Florida's pineapple production was nearly eliminated by cold temperatures, so is Hawaii's moving east due to increasing production costs. Pineapple production for the U.S. market is now much greater in Central America than it ever was in Hawaii. Despite the fact that Hawaii is still a major pineapple producer, many Hawaiian nurserymen are now entering the exotic bromeliad market, with some major facilities producing foliage and decorative flowering species of bromeliads.

Which Bromeliads Are Imported?

Of 50 genera and over 2,000 species of bromeliads, only a relative few are commonly imported. Of these, much the majority are from cultivated stock. Plants of wild origin are imported to a much more limited degree. These few are used primarily as propagation stock, hybrid parent stock, limited sales to collectors, and as herbarium material. Many, if not most of the bromeliads imported, are artificially propagated hybrids, patented varieties not otherwise available in this country.

Economics

Bromeliad cuttings can be grown faster and cheaper in nurseries abroad than in the USA. Many such facilities exist in Puerto Rico, Guatemala, Costa Rica, Colombia and, to a lesser extent, in several other Latin American countries. The largest bromeliad nursery in the world is in Holland, and it funnels millions of seedlings and finished plants annually into the U.S. market. Plants of the genus *Tillandsia* are grown in large overseas operations where a combination of selected climatic conditions and lower production costs make production there more lucrative. These plants, often incorporated into novelty uses, cannot be sent to the USA as finished products for direct sale. Nurseries here must, at the very least, house them for a time, pending sales. However, these plants are usually brought in as cuttings or pre-finished, and grown out for an extended period to produce a superior, unblemished, finished product.

The Need to Import Bromeliads

Commercial Competition

The bromeliad market is extremely competitive and the biggest companies vie for market share with a steady stream of beautiful new patented varieties. Hybridizers are working constantly to produce ever more spectacular and hardy varieties for the marketplace. This work is fueled by one thing: new stock. The competition for finding and being the first to use new superior clones and new species of bromeliads, especially in the genera *Guzmania*, *Vriesia*, and *Aechmea*, is stiff. At stake may be the very survival of the U.S. bromeliad industry. Many superior hybrids have been produced in the USA and are now grown under licensing agreements here and abroad. A single patented variety could be worth millions to the patent holder.

Research

Florida is the center of bromeliad research. The Marie Selby Botanical Garden and the Mulford B. Foster Bromeliad Identification Center employ full-time research staff investigating the taxonomy and physiology of bromeliads. Researchers and scientists from all over the world come to Florida to involve themselves with these studies. Importation of fresh research material is essential to the survival of these institutions. In no less a manner, the results of their research are essential to the survival of the bromeliad industry.

Conservation

Great concern has been expressed in recent years about the possible imminent demise of many tropical organisms, including bromeliads. Recently, seven species of bromeliads were added to the CITES list of endangered species. Rampant habitat destruction is the major cause of their decline in nature and can be attributed to many factors. Land-clearing for cattle production and other agricultural use leads the list of habitat-destroying activities. New, full-sun varieties of coffee and cacao are causing great tracts of montane forest to be cleared where once some canopy, often bearing epiphytic bromeliads, was left for shading the crops. Traditional crops such as bananas and now pineapples have caused the decimation of much lowland forest for their production. Logging, mining and human encroachment have eliminated much critical habitat.

Importing bromeliads for the purpose of saving rarer species and conserving the biological diversity of others is now a reality. Already some species exist in cultivation that are known or thought to be extinct in their natural habitats. These and other species of bromeliads, still found in their natural habitats, but declining from various factors, are being cultivated with an eye toward reintroduction. All this is made possible by bromeliad importation.

The Argument Against Importing Bromeliads

Human Health Risks

Misinformation has been responsible for some minor hysteria about the "problem" of mosquitoes in bromeliads. Both of the two species of mosquito known to develop habitually as larvae in bromeliad tanks in Florida, are native to Florida, and neither is known to be a vector of diseases of humans. It appears that they are no more than a nuisance (Frank 1994). Even though some neotropical mosquitoes have larvae specialized to existence in bromeliad tanks and have adults that vector diseases to humans, none of these has become established in Florida. Larvae of a few other mosquito species sometimes inhabit water in bromeliad tanks in Florida, but bromeliad tanks are just a small part of their habitat, and they would occur whether or not bromeliad tanks were available to them. It is fairly easy to control bromeliad-inhabiting mosquitoes, of native or foreign origin, in nurseries and well-maintained landscapes. Much of the misinformation is spread by the pest-control industry which profits from the public's fear of disease.

A similar misinformation campaign has been mounted against a native bromeliad, *Tillandsia usneoides* (Spanish moss). Much profit has been made by pest-control companies by spraying copper to eliminate the 'moss' after convincing people that it kills their trees, a premise long ago proved false.

Risks to Agriculture and Horticulture

Bromeliads have been imported into the USA for more than a hundred years. So far, no pest of foreign origin, whose presence in Florida is attributed to bromeliad imports, has been shown to affect plants other than bromeliads.

Bromeliads collected in the field in the tropics may house all sorts of insects and other invertebrate animals, which are often difficult to detect because of the plants' structure. USDA inspectors at airports annually discover large numbers of insects, molluscs, and plant pathogens in imported bromeliads, as a result of carelessness on the part of the shippers. If plants have to be collected in the field, they should be cleaned carefully and then dipped in a suitable chemical pesticide.

Bromeliads shipped from nurseries abroad are likely to be much cleaner of insects in general than are plants collected in the field. However, those pests that do hitchhike in such plants are more likely to be specific pests of bromeliads. Most such pests have so far been species of scale insects specific to bromeliads. Again, the best solution is to dip all plants in a suitable chemical pesticide. The onus is on the importer to make sure that only pest-free plants are imported, because USDA inspectors are too short-staffed to inspect more than a small fraction of plants. A pest of concern which **has** become established in southern Florida due to its hitchhiking in imported bromeliads is *Metamasius callizona* (Chevrolat) (Frank & Thomas 1994). Other pests as important as *M. callizona* could arrive in imported bromeliads if importers are not extremely careful. Vigilance is now required to detect and control this weevil pest in nurseries and collections in Florida.

Risks to the Native Flora

No exotic species of bromeliad has become established in nature in Florida, even on a limited scale, even though some species could certainly survive. In biological terms, bromeliads of foreign origin do not seem to be "invasive" in Florida even when they originate from places of similar climate. Reasons for their lack of invasiveness have not been investigated.

Presence of *Metamasius callizona* in nature in four counties in Florida is of more concern. Its continued spread is believed to be in part due to transport of infested plants and in part to flight by adults. What effect this weevil will ultimately have on the bromeliad flora of southern Florida is unknown. A hope is that insect biological control agents will be discovered in its native range, will be introduced successfully into Florida, and will succeed in controlling this pest in nature.

Conclusion

Bromeliad importation appears to be fairly benign. Lacking strong evidence to the contrary, bromeliads should continue to be imported as an important part of Florida's horticultural industry and as fuel for its research facilities. Hundreds of jobs directly related to the bromeliad industry, and thousands indirectly related, may be at stake.

The bromeliad industry helps make Florida the top state in the nation in horticultural production. Our subtropical climate lends itself well to landscaping with bromeliads, and bromeliads now add beauty to countless homes, business, parks, public works, tourist attractions and public buildings. This same climate allows the cultivation of a wide and ever-increasing variety of threatened and endangered bromeliad species. Coupling this with a fairly low incidence of pest infestation leaves little grounds for the restriction of bromeliad imports.

ACKNOWLEDGMENTS

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PRECINCTIVE INSECT SPECIES IN FLORIDA

J. H. FRANK[1] AND E. D. MCCOY[2]
[1]Entomology & Nematology Department, University of Florida,
Gainesville, FL 32611-0620, USA

[2]Biology Department, University of South Florida,
Tampa, FL 33620-5150, USA

ABSTRACT

The number of insect species now occurring in Florida is estimated at about 12,500. Statements from specialists in 28 insect taxa (at the level of family or higher), representing some 40% of the fauna, suggest that about 12% of the total fauna (13% of the indigenous fauna, with range 0-43% among taxa) is precinctive. Immigrants form less than 8% of the total fauna. Only 42 (0.3%) species are known to have been introduced deliberately, for purposes of biological control. The proportions of immigrants and of precinctive species are far lower than in the Hawaiian insect fauna, but the proportion of immigrants exceeds that of the fauna of the contiguous United States as a whole.

Key Words: Adventive species, indigenous species, precinctive species, immigrant species, diversity.

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RESUMEN

Se estima que el número de especies de insectos existentes en la Florida es cercano a 12500. Opiniones de especialistas en 28 grupos de insectos (a nivel de familia o superior) que representan un 40% de la fauna, sugieren que cerca de 12% de la fauna total (13% de la fauna indígena, con intervalo 0-43% entre grupos) es precinctiva. Los inmigrantes constituyen menos del 8% de la fauna total. Solo 42 (0.3%) especies han sido introducidas intencionalmente, con fines de control biológico. Las proporciones de especies inmigrantes y precinctivas son mucho menores que en la fauna de insectos de Hawaii, pero la proporción de inmigrantes excede la de la fauna de los Estados Unidos contiguos como un total.

Many generalizations about the diversity of insects have been drawn from the European fauna, especially the fauna of the British Isles. This has been possible because of virtually complete checklists published, for example, by the Royal Entomological Society. Checklists are available for other locations, as well, such as Hawaii. A second (revised) edition of a computerized checklist of the arthropod fauna reported from Hawaii in the literature has just been published (Nishida 1994). Even though it is stated to be incomplete and may contain errors, it documents some striking facts. For example [using our terminology (Frank & McCoy 1990) rather than Nishida's (1994) terms], it gives the number of **indigenous** insect species as 5,059 (4,980 **precinctive** and 79 **indigenous but not precinctive**), and the number of **adventive** species as 2,549 (2,137 **immigrant** and 412 **introduced**). These proportions are so different from our conception of the Florida insect fauna that we thought it useful to compare the faunas of Florida and Hawaii.

Because we shall use precise terminology (Frank & McCoy 1990) to make comparisons between faunas, it is important that we reiterate what the terms mean. The six categories into which we shall place insects are **indigenous**, **precinctive**,[1] **indigenous but not precinctive**, **adventive**, **immigrant**, and **introduced**. The six categories are delimited as follows.

Indigenous: native

- A. **Precinctive**: native to and restricted to the area specified (the usage follows Sharp 1900)
- B. **Indigenous but not precinctive**: native to the area specified and elsewhere

Adventive (= non-indigenous): not native; arrived from elsewhere

- C. **Immigrant**: not native to the area specified and arrived there by means other than purposeful introduction, such as flight, walking, swimming, rafting, phoresy, hitchhiking in cargoes, and as aerial plankton (the usage follows Sailer 1978, although he neither provided a definition nor used the term consistently)
- D. **Introduced**: not native to the area specified and arrived there by means of purposeful introduction (the usage follows Zimmerman 1948)

There is no checklist of the insect fauna of Florida, although works including all known species of Ephemeroptera, Odonata, Blattodea, Isoptera, Orthoptera and Lep-

[1]Later in this paper we use the noun precinction (the state of being restricted to a specified area) which was used in English in 1730 (OED 1971). It bears the same relationship to precinctive as endemism bears to the adjective endemic.

idoptera, and partial checklists of one, or a few related families in other orders, have been published. Therefore, we estimated the total number of insect species now occurring in Florida and, using this total number as a basis, we estimated the numbers of **immigrant** species, **precinctive** species, and **indigenous but not precinctive** species (number of **introduced** species was known). With these estimates in hand, we could then compare the insect faunas of Florida and Hawaii.

THE TOTAL NUMBER OF INSECT SPECIES IN FLORIDA

Several ways exist to estimate the total number of insects in Florida. One could, for example, use the combined knowledge of expert taxonomists (e.g., Gaston 1991), or extrapolate from extensive field collections (e.g., Stork 1988, Hodkinson & Casson 1991), or extrapolate from ratios of numbers of insect species to numbers of plant species (e.g., Hodkinson & Casson 1991, Gaston 1992). We have chosen yet another way, to extrapolate from a particularly well-known group, the beetles (see Erwin 1982, 1988; Stork 1988). Although there is no checklist of the insect fauna of Florida, Michael C. Thomas is constructing a computerized catalog of Florida Coleoptera. This catalog will include all species documented in the literature and all species represented in the Florida State Collection of Arthropods, with entries corrected in consultation with specialist taxonomists. Thomas informs us that the number of species names listed is now over 4,000, and he expects the total to reach 5,000 when documentation is complete. Given that beetles comprise 40% of all insect species (Borror et al. 1976), and assuming that the composition (proportions among orders) of the insect fauna of Florida is not especially divergent from other faunas, then the total number of insect species now occurring in Florida should be about (5,000 x 100/40 =) 12,500.

THE NUMBERS OF IMMIGRANT AND INTRODUCED INSECT SPECIES IN FLORIDA

We documented 271 **immigrant** insect species as newly recorded in the literature from 1971 to 1991 (Frank & McCoy 1992). We have not surveyed the older literature to the same purpose, but will attempt to extrapolate. We adopted the anthropocentric concept that species occurring in Florida before Columbus' first voyage are indigenous. Immigrant species probably did arrive (as stowaways) with early Spanish colonists, but we believe that the number of species immigrating has increased very much in recent decades (see Frank & McCoy 1993). We attribute this recent increase to the arrival of insects (as stowaways) in the cargoes, especially cargoes of plants, that have been shipped to Florida in ever-increasing numbers. Although dozens of immigrant species were known as pests in the 19th century, the number is now in the hundreds. Based on our documentation of recent immigrations, we would place the number of **immigrant** species now present in Florida at about 1,000; the estimate derived from statements of specialist taxonomists (see below) is about 950.

We also documented 42 **introduced** insect species as established in Florida (Frank & McCoy 1993). Many more species have been brought to Florida deliberately (Frank & McCoy 1993, 1994), and 151 of these have been released for biological control purposes.

THE NUMBER OF PRECINCTIVE INSECT SPECIES IN FLORIDA

Determining which taxa are precinctive is an undertaking fraught with uncertainties, and it is worth spending some time to understand clearly what it means to be precinctive. Precinctive taxa often are of great interest simply because they are unique (Australian marsupials or the "Teesdale Rarities," for instance) or because they may tell us something interesting about biogeographic processes or for numerous other reasons. Perhaps the most interesting question to be asked about precinctive taxa is: What creates them? We may proceed to answer this question by looking for areas with large numbers of precinctive taxa and then inferring a cause based upon which particular areas are singled out. Like all conclusions generated in this fashion, the "cause" decided upon may not be totally convincing. A classic example may be found in patterns of precinctive taxa on isolated oceanic islands (Briggs 1966, 1969; McDowell 1968, 1970; McCoy & Heck 1987). It seems clear that precinctive taxa are produced by precisely the same biotic and abiotic constraints that circumscribe ranges in general. Indeed, it should be apparent that there is nothing unusual about precinctive taxa per se; every taxon is precinctive to some geographical area. Precinctive taxa typically become useful and interesting when they are confined to relatively-small areas, especially if those areas harbor large numbers of them. In such cases, one quite naturally assumes that restriction of many species to small areas is improbable and, consequently, that very powerful biotic or abiotic range limitations have been at work. Rotondo et al. (1981), for example, illustrate the role of island integration in promoting high numbers of precinctive taxa on some Pacific islands, especially the Hawaiian Islands. So, how does one determine when a certain level of precinction in an area is improbable? For example, is the 10%-level of precinction thought to be present among marine invertebrates in the northern Gulf of Mexico (Hedgpeth 1953, McCoy & Bell 1985) truly unusual? We suppose that to find out, one could divide the eastern coast of the Western Hemisphere into segments, each equal the length of the northern Gulf of Mexico, assign species to them in a weighted random fashion, and compute resulting levels of precinction. Such a procedure would be overkill, though, for it is almost always relative levels of precinction that are deemed out of the ordinary. In the Gulf of Mexico, it is true that levels of precinction are low in most places, so an area with a level of 10% stands out. It would not stand out if, say, 8% precinction were the rule everywhere else in the Gulf. One could probably argue, therefore, that any changes in precinction, even small ones, deserve investigation. The roles of various limiting factors in circumscribing ranges may be understood further by such investigations. One should keep in mind, however, that the identification of areas of unusual levels of precinction is a subjective and relative process. The criterion employed usually will be consensus. Failure to acknowledge these facts about how precinction is recognized may lead to some unusual exercises in logic. Consider, for example, a hypothetical case of three adjacent areas divided by arbitrary boundaries. Suppose that researchers have identified areas "A" and "C" as possessing relatively many precinctive species, and have produced some geological explanation for their isolation. By concensus, then, "A" and "C" are touted as unusually rich areas of precinction, and the other area, "B," is forgotten. This scenario might be appropriate if, say, "A" and "C" each had 6 precinctive species and "B" only 2. It might not be appropriate, however, if "A" and "C" each had 10 precinctive species and "B" none. One might feel compelled in the second case to single out "B" as an unusually poor area of precinction, and try instead to explain this "phenomenon." Of course, the explanation produced is likely to be the reciprocal of one that would be produced for relatively-high levels of precinction in "A" and "C." Because of inherent subjectivity and relativity, the entire process of identifying unusual levels of precinction is dangerously prone to circularity (see, for example, Guillory 1979). Bearing these caveats in mind, we shall attempt to provide some estimates of the number of insect taxa precinctive to Florida.

We felt estimates of the numbers of precinctive species could be achieved best by asking a large number of specialists with knowledge of the Florida fauna at the family level (or a higher level) to prepare a statement for publication (cf. Muller et al. 1989). Each statement would be published under the name of the specialist who prepared it, and would give the total number of **indigenous** species, subdivided into the two subcategories (**precinctive**, and **indigenous but not precinctive**), as recorded in the literature. Subspecies would not be considered. Species present at the time of Columbus would be considered **indigenous**. Indigenous species reported only from Florida (not from neighboring states, nor from the West Indies, nor from other regions) would be considered **precinctive**. Obviously, this determination requires substantial judgment by the specialists. Species believed to be indigenous to the Greater Antilles or to the southeastern USA, that also occur in Florida, would be considered **indigenous but not precinctive**. The specialists' statements would not only allow an overall estimate of the proportion of **precinctive** species, but would allow examination of variation from taxon to taxon. We contacted colleagues who study a broad cross-section of the fauna, and it was their interests that selected the taxa included, so we felt that there is no biological bias in selection of taxa. Their statements included about 40% of the estimated 12,500 species of Florida insects, and allowed the compilation shown in Table 1.

Mayflies (Ephemeroptera)

Manuel L. Pescador, Entomology—Water Studies, Florida A&M University,
Tallahassee, FL 32308-4100, USA

Florida has a mayfly fauna of relatively low diversity. Of the 71 species known in the state, 23 are indigenous, 10 of which are **precinctive** and 13 are not precinctive. The precinctive species include 3 of Baetidae [*Baetis alachua* (Berner), *Callibaetis floridanus* Banks, and *C. pretiosus* Banks], 3 of Metretopodidae [*Siphoplecton brunneum* Berner, *S. fuscum* Berner, and *S. simile* Berner], one of Heptageniidae [*Stenacron floridense* (Lewis)], one of Ephemeridae [*Hexagenia orlando* Traver], and 2 of Caenidae [*Brachycercus maculatus* Berner and *B. nasutus* Soldan]. There is no evidence to suggest any mayfly dispersal from the West Indies to Florida, and the mayfly faunas of the two areas show no phyletic relationships.

Dragonflies and damselflies (Odonata)

Sidney W. Dunkle, Biology Department, Collin County Community College,
Plano, TX 75074, USA

An estimated 144 species of Odonata were indigenous to Florida at the time of European discovery. Of these, 104 are dragonflies (Anisoptera) and 40 are damselflies (Zygoptera). Of the 144 indigenous Odonata, 5 (4 Anisoptera, 1 Zygoptera) are **precinctive**. There are now 12 established species of **immigrant** Odonata, one of them [*Crocothemis servilia* (Drury)] from Asia, 3 [*Celithemis elisa* (Hagen), *Enallagma basidens* Calvert and *E. civile* Hagen] from North America, and 8 from the neotropics. No species of Odonata has been **introduced** (deliberately) to Florida. Additionally, 7 species have been found as vagrants, without breeding populations. More than a third (163 species) of the North American odonate fauna has now been found in Florida. This information was extracted from a publication by S. W. Dunkle (1992. Distribution of dragonflies and damselflies in Florida. Bull. American Odonatology 1(2): 29-50).

TABLE 1. VARIATION AMONG TAXA IN PROPORTION OF PRECINCTIVE SPECIES AND NUMBER OF IMMIGRANT SPECIES.

Taxon	Indigenous	Precinctive		Immigrant
EPHEMEROPTERA	23	10	(43%)	48
ODONATA	144	5	(4%)	12
BLATTODEA	25	1	(4%)	15
ISOPTERA	14	3	(21%)	3
ORTHOPTERA	232	41	(18%)	10
HEMIPTERA				
Lygaeidae	105	10	(10%)	10
Miridae	175	36	(21%)	10
HOMOPTERA				
Fulgoroidea	214	34	(16%)	6
Coccidae	14	3	(21%)	30
NEUROPTERA	85	1	(1%)	0
COLEOPTERA				
Carabidae	365	40	(11%)	3
Staphylinidae	328	74	(23%)	15
Scarabaeidae	275	45	(16%)	17
Lampyridae	49	20	(41%)	1
Nitidulidae	51	3	(6%)	6
flat bark beetles[1]	38	0	(0%)	18
Bruchidae	30	0	(0%)	14
Curculionidae[2]	526	115	(22%)	45
LEPIDOPTERA				
Tortricidae	239	26	(11%)	9
Sesiidae	41	2	(5%)	0
Geometridae	244	33	(14%)	5
butterflies[3]	199	0	(0%)	1
DIPTERA				
Culicidae	74	1	(1%)	4
Tabanidae	99	3	(3%)	0
Tephritidae	52	4	(8%)	2
HYMENOPTERA				
Ichneumonidae	340	20	(6%)	5
Aphelinidae	30	3	(10%)	1

[1]Silvanidae+Passandridae+Laemophloeidae
[2]excluding Brentidae+Anthribidae+Scolytidae+Platypodidae
[3]Papilionoidea+Hesperioidea

TABLE 1. VARIATION AMONG TAXA IN PROPORTION OF PRECINCTIVE SPECIES AND NUMBER OF IMMIGRANT SPECIES.

Taxon	Indigenous	Precinctive		Immigrant
Formicidae	149	14	(11%)	52
TOTAL (THIS SAMPLE)	4,160	547	(13%)	342
TOTAL (WHOLE FAUNA)	11,512	1,514	(13%)	946

[1]Silvanidae+Passandridae+Laemophloeidae
[2]excluding Brentidae+Anthribidae+Scolytidae+Platypodidae
[3]Papilionoidea+Hesperioidea

Cockroaches (Blattodea)

P. G. Koehler and R. J. Brenner, Entomology & Nematology Department,
University of Florida, Gainesville, FL 32611-0630,
and Medical and Veterinary Entomology Research Laboratory, USDA-ARS,
1600 SW 23rd Drive, Gainesville, FL 32604, USA

The cockroach fauna of Florida has recently been cataloged and is taxonomically diverse compared to that of other U.S. states. There are 25 indigenous species in 17 genera and 4 families. One species, *Arenivaga floridensis* Caudell, is **precinctive**. It is the only species of this genus in the eastern USA, and is a remnant of a larger, xeric-adapted biota that was abundant during the last glacial period. There are 24 cockroach species **indigenous but not precinctive**. The range of 8 extends to the West Indies, whereas the range of 9 extends to the U.S. mainland outside Florida. An additional 3 species range from Florida to the U.S. mainland and into Central America, and 2 species range from the West Indies into Florida and to the U.S. mainland outside Florida. The range of the final 2 species is from the West Indies into Florida and into Central America. The Florida fauna also includes 15 **immigrant** species that arrived from the Old World. The major pest species of cockroaches are all immigrants.

Termites (Isoptera)

Rudolf H. Scheffrahn, FLREC - University of Florida, 3205 SW College Avenue,
Ft. Lauderdale, FL 33314-7799, USA

The termite fauna of Florida, although taxonomically diverse, is a well-studied group. Fourteen indigenous species from 8 genera and 3 families are represented. Three species, *Calcaritermes nearcticus* Snyder, *Neotermes luykxi* Nickle & Collins, and *Amitermes floridensis* Scheffrahn et al. are **precinctive**. Of the remaining 11 indigenous species, six are also recorded from the West Indies or Neotropical mainland, three occur on the U.S. mainland outside Florida, and two occur both on the U.S. mainland and offshore. Based on extensive recent collections in the West Indies, it is unlikely that species now thought to be precinctive to Florida will be found elsewhere in the future. The Florida fauna also includes 3 **immigrant** species.

Grasshoppers and crickets (Orthoptera)

Thomas J. Walker, Entomology & Nematology Department, University of Florida,
Gainesville, FL 32611-0620, USA

Except for an eneopterine cricket, probably from Taiwan, recently established in south Florida, these figures are from S. B. Peck, T. J. Walker & J. L. Capinera (1992. Distributional review of the Orthoptera of Florida. Florida Entomol. 75: 329-342). There are 242 species of Orthoptera known to occur in Florida. Of these, 232 are indigenous, 191 are **indigenous but not precinctive**, 41 are **precinctive**, and 10 are post-Columbian **immigrants**. For the 87 species of Caelifera, the numbers are 87, 70, 17, and 0, and for the 155 Ensifera, they are 145, 121, 24, and 10.

Seed bugs (Hemiptera: Lygaeidae)

R. M. Baranowski, University of Florida Institute of Food & Agricultural Sciences,
Tropical Research and Education Center, Homestead, FL 33031, USA

There are 115 species of Lygaeidae known to occur in Florida. Ten species are known only from Florida, and 95 more are likewise considered indigenous. Ten species are considered recent **immigrants** based on habitat distribution and the probability of their being collected by general collectors. Thus, of the 115 known Florida species, 105 are known from outside of Florida.

Plant bugs (Hemiptera: Miridae)

A. G. Wheeler, Jr. and T. J. Henry, Bureau of Plant Industry,
Pennsylvania Department of Agriculture, Harrisburg, PA 17110,
and Systematic Entomology Laboratory, USDA-ARS,
c/o National Museum of Natural History, Washington, DC 20560, USA

The Floridian mirid fauna consists of 175 indigenous (= native) species, including 36 (21%) that are **precinctive**. These figures are based on the most recent catalog of the group, by T. J. Henry & A. G. Wheeler (1988. Family Miridae Hahn 1833 (= Capsidae Burmeister 1835), The plant bugs, p. 251-507 *in* T. J. Henry and R. C. Froeschner [eds.]. Catalog of the Heteroptera, or True Bugs, of Canada and the Continental United States. E. J. Brill; Leiden). The total number of mirids recorded from Florida increases to 185 with the addition of 10 species that we consider to be **immigrant**.

Planthoppers (Homoptera: Fulgoroidea)

Lois B. O'Brien, Entomology—Biological Control, Florida A&M University,
Tallahassee, FL 32307-4100, USA

In 7 of the 11 families of Fulgoroidea found in the U.S. (except Delphacidae, Derbidae, Flatidae, and Tropiduchidae), most species occur in the western U.S. In one family, Tropiduchidae, all 3 species known from the U.S. occur in Florida; one is **precinctive**, one indigenous with extensions to nearby states and Cuba, and one indigenous to Florida, Cuba, and Hispaniola. However, many species in the Greater Antilles were identified before genitalia were used for identification, and some records are suspect. Species from the Lesser Antilles are better known and, except for Delphacidae, at least 90% are precinctive to one island. Species that were described from the Greater Antilles have been discovered in Florida during the last 50 years, but their date of arrival cannot be pinpointed. Thirty-four (16%) of 214 indigenous Florida species of Fulgoroidea are precinctive. There are 6 **immigrants**, including 3 pantropical pests of corn and sugarcane which arrived in this century.

Soft scales (Homoptera: Coccidae)

Avas B. Hamon, Florida State Collection of Arthropods, P.O. Box 147100, Gainesville,
FL 32614-7100, USA

Fourteen species of the soft scale family Coccidae are indigenous to Florida. Of these 14 species, only 3 are **precinctive**, and the other 11 are **indigenous but not precinctive**. Thirty **immigrant** species of soft scales are reported from Florida.

Lacewings, antlions, and relatives (Neuroptera)

Lionel A. Stange, Florida State Collection of Arthropods, P.O. Box 147100,
Gainesville, FL 32614-7100, USA

There are 85 species of Neuroptera (including Megaloptera) indigenous to Florida. Only one species, *Mantispa floridana* Banks, is **precinctive** to Florida. There are no adventive species. At least 4 species remain to be described.

Ground beetles (Coleoptera: Carabidae)

P. M. Choate, Entomology & Nematology Department, University of Florida,
Gainesville, FL 32611-0620, USA

Florida has 365 indigenous species of ground beetles. Of these, 40 are **precinctive**, while 325 are **indigenous but not precinctive**. There are 3 **immigrant** species.

Rove beetles (Coleoptera: Staphylinidae, *sensu stricto*)

J. H. Frank, Entomology & Nematology Department, University of Florida,
Gainesville, FL 32611-0620, USA

The traditional concept of Staphylinidae is used here, to include Micropeplinae (no species yet reported from Florida), but exclude Scaphidiidae [-inae], Dasyceridae [-inae], and Pselaphidae [-inae]. There are 328 indigenous species of Staphylinidae in Florida, including 74 **precinctive** species and 254 **indigenous but not precinctive** species. In addition, 15 **adventive** species are established in Florida, all of which are **immigrants** (none of them was **introduced**). At very least a quarter of the staphylinid fauna is yet unrecorded: its eventual recording will increase the totals in the various categories. The proportion of precinctive species may be reduced by modern reports of the staphylinid fauna of Alabama, Georgia, and the Greater Antilles.

Scarab beetles (Coleoptera: Scarabaeidae)

Robert E. Woodruff, Emeritus Entomologist, Florida State Collection of Arthropods,
P.O. Box 147100, Gainesville, FL 32614-7100, USA

Two volumes (of 3) in the series "The Scarab Beetles of Florida" have been published by R. E. Woodruff (1973. Part I. Arthropods of Florida and Neighboring Land Areas, Vol. 8) and by R. E. Woodruff & B. M. Beck (1989. Part II. Arthropods of Florida and Neighboring Land Areas, Vol. 13), and the family is better known than most. There are 292 species recorded from Florida of which 17 are **immigrant**, thus 275 are indigenous and of these 45 are **precinctive**!

Fireflies (Coleoptera: Lampyridae)

James E. Lloyd, Entomology & Nematology Department, University of Florida,
Gainesville, FL 32611-0620, USA (with comments on myth, theory, and reality)

There have been 49 indigenous species of fireflies in 8 genera reported to occur in Florida, with 20 of these in 6 genera being **precinctive**. This tally includes 11 species for which I and others (whom I have supplied with living fireflies for research) have used informal designations (e.g., *Photuris* sp. "B", *Photinus* "slow-pulse" *consimilis*).

These numbers bear only quaint relationship to Florida fireflies in nature. Misidentifications of cabinet specimens account for a few names in the literature, these being made before the magnitude of the sibling species problem was appreciated. Some species known to occur in Florida are not counted because they have never been mentioned in the literature, and some that certainly are here for they are known from localities nearby to the north, but cannot now be counted. One species appears to be a repeated **immigrant** from Central America, and may occasionally survive a year or so before disappearing. The most realistic estimate (not prediction) that I can give, these problems considered, is that there are 57 indigenous species in 11 genera in Florida, of which 17 species in 6 genera are precinctive. But, what bearing do such presumptively good species have to real, that is, actual (isolation of gene pools) diversity as it exists in nature? Systematists have multiple species concepts and dissatisfaction with all of them, and I am confident that an interplanetary visitor would avoid taking sides in this, and probably not do any counting, for scientific not sociable reasons. A species count for Florida fireflies is at once myth, theory, and reality.

Sap beetles (Coleoptera: Nitidulidae)

Dale H. Habeck, Entomology & Nematology Department, University of Florida,
Gainesville, FL 32611-0620, USA

There are 51 indigenous species of Nitidulidae in Florida including one species of Cybocephalinae, a group sometimes given family status. Only 3 species are **precinctive** and 48 are **indigenous but not precinctive**. Six species are, or are presumed to be, adventive (**immigrants**).

Flat bark beetles (Coleoptera: Laemophloeidae, Silvanidae, Passandridae)

Michael C. Thomas, Florida State Collection of Arthropods, P.O. Box 147100,
Gainesville, FL 32614-7100, USA

Of the 56 species of flat bark beetles recorded from Florida by M. C. Thomas (1993. The Flat Bark Beetles of Florida (Coleoptera: Silvanidae, Passandridae, Laemophloeidae). Arthropods of Florida & Neighboring Land Areas, Vol. 15), a total of 38 species (Silvanidae, 10; Passandridae, 2; Laemophloeidae, 26) can be considered indigenous. The other 18 are **immigrant** species. There are no **precinctive** species of flat bark beetles in Florida. Of the indigenous species, the major part of the distributions of 30 species is to the north of Florida; the distributions of the remaining 8 species are primarily Neotropical.

Seed beetles (Coleoptera: Bruchidae)

John M. Kingsolver, Florida State Collection of Arthropods, P.O. Box 147100,
Gainesville, FL 32614-7100, USA

Of the 44 species of Bruchidae now recorded from Florida, 30 are indigenous, including 23 which are part of the eastern U.S. fauna, 2 which are Circumcaribbean, and 5 common to the West Indies and Florida. There are no **precinctive** species. Of the 14 **immigrant** species, 4 are cosmopolitan “tramp” species in stored legume seeds, 3 are South American, and 7 are Central American. No species was **introduced** (deliberately).

Weevils (Coleoptera: Curculionidae, *sensu lato*)

Charles W. O’Brien, Entomology—Biological Control, Florida A&M University,
Tallahassee, FL 32307-4100, USA

There are 526 indigenous species of Curculionidae in Florida. The number of **precinctive** species of Curculionidae is 115 and the number of **indigenous but not pre-**

cinctive species is 411. Among these species of indigenous Florida weevils there are 46 which have distributions in the West Indies and 35 which have distributions which include Mexico and/or Central America. It is evident from recent collections, which reduced the number of species that were previously thought to be precinctive in Florida but are now known to be in the Greater Antilles and other West Indian islands as well, that the number of precinctive species will be reduced with further collecting. In addition, 50 **adventive** species are established in Florida; 5 of these were **introduced** (deliberately) for biological control of weeds, and 45 are **immigrants**.

Leaf-rolling moths (Lepidoptera: Tortricidae)

John B. Heppner, Florida State Collection of Arthropods, P.O. Box 147100,
Gainesville, FL 32614-7100, USA

In Florida are reported to occur 239 indigenous species of Tortricidae, of which 26 (11%) are **precinctive**. In addition, there are 9 **immigrant** species.

Clear-winged moths (Lepidoptera: Sesiidae)

Larry N. Brown, Environmental Studies, Inc., P.O. Box 14244
Tallahassee, FL 32317, USA

Historically, the clearwing moths (family Sesiidae) have been rather difficult to collect, because adults mimic wasps, fly very fast, are rather inconspicuous, and are only emergent for a short period of time. The development of scent attractants (pheromones) within the last two decades has caused tremendous numbers of clearwing moths (mainly males) to be collected, representing many species. The total number of species of Sesiidae indigenous to Florida is 41 as documented by L. N. Brown & R. F. Mizell (1993. The clearwing borers of Florida (Lepidoptera: Sesiidae). Tropical Lepidoptera 4 (suppl. 4): 1-21), in which no **immigrant** species are recorded. Only two species are known only from Florida. This is not too surprising because the sesiids clearly colonized Florida from areas to the north and west.

Measuringworms (Lepidoptera: Geometridae)

John B. Heppner, Florida State Collection of Arthropods, P.O. Box 147100,
Gainesville, FL 32614-7100, USA

In Florida are reported to occur 244 indigenous species of Geometridae, of which 33 (14%) are **precinctive**. In addition, there are 5 **immigrant** species.

Butterflies (Lepidoptera: Papilionoidea, Hesperioidea)

Thomas C. Emmel, Zoology and Entomology Departments, University of Florida,
Gainesville, FL 32611-0620, USA

The butterfly fauna of Florida is composed of a mixture of temperate species extending into the peninsula from the north and west, and tropical species invading from the south. There are 199 indigenous species of butterflies in Florida, including 120 Papilionoidea (10 Papilionidae, 24 Pieridae, 40 Nymphalidae, 8 Satyridae, 3 Danaidae, 1 Libytheidae, 33 Lycaenidae, and 1 Riodinidae) and 79 Hesperioidea (3 Megathymidae and 76 Hesperiidae). These totals include no **precinctive** species, and 199 **indigenous but not precinctive** species. One species, *Pieris rapae* L., is an **immigrant**.

Mosquitoes (Diptera: Culicidae)

P. E. Kaiser, Medical & Veterinary Entomology Research Laboratory, USDA-ARS,
1600 SW 23rd Drive, Gainesville, FL 32604, USA

In Florida, the family Culicidae contains 12 genera and 74 indigenous species. The genera and number of species for each are: *Aedes* (18), *Anopheles* (18), *Coquillettidia* (1), *Culex* (14), *Culiseta* (2), *Deinocerites* (1), *Mansonia* (2), *Orthopodomyia* (2), *Psorophora* (10), *Toxorhynchites* (1), *Uranotaenia* (2), and *Wyeomyia* (3). Only one species, *Anopheles quadrimaculatus* sibling species C_1, is **precinctive** to Florida, and additional research may extend its range to southern Georgia. The other 73 species have distributions outside Florida. There also are 4 **immigrant** species.

Horseflies and deerflies (Diptera: Tabanidae)

Richard H. Roberts, Florida State Collection of Arthropods, P.O. Box 147100,
Gainesville, FL 32614-7100, USA

Ninety-nine species of Tabanidae were listed by C. M. Jones & D. W. Anthony (1964. The Tabanidae (Diptera) of Florida. USDA-ARS Tech. Bull. 1295) as occurring in Florida. Of the species listed in that bulletin (which now needs revision), 3 are **precinctive** and none are adventive.

Fruit flies (Diptera: Tephritidae)

Gary J. Steck, Florida State Collection of Arthropods, P.O. Box 147100,
Gainesville, FL 32614-7100, USA

Florida is home to 52 species of indigenous tephritid flies based on published records, which are easily retrievable from R. H. Foote, F. L. Blanc & A. L. Norrbom (1993. Handbook of the Fruit Flies (Diptera: Tephritidae) of America North of Mexico. Comstock; Ithaca, New York). Of these, only 4 species are **precinctive** and the remaining 48 are **indigenous but not precinctive**. Further collecting in Georgia would almost surely reveal the presence of one of the Florida precinctive species; further collecting in the Caribbean would potentially reveal the presence of one or two of the others. An additional 6 immigrant fruit fly species have been recorded from Florida, but only two (Caribbean fruit fly and papaya fruit fly) have successfully colonized. The other 4 immigrant species either have been eradicated (e.g., Mediterranean fruit fly) or never successfully established.

Ichneumon wasps (Hymenoptera: Ichneumonidae)

Virendra K. Gupta, Entomology & Nematology Department, University of Florida,
Gainesville, FL 32611-0630, USA

In 1979, 185 species of Ichneumonidae were reported from Florida by K. V. Krombein, P. D. Hurd & D. R. Smith, eds. (1979. A Catalog of Hymenoptera in America North of Mexico. Smithsonian Institution Press; Washington, DC, 3 vols). Another 160+ species were reported in several revisionary works of G. H. Heinrich, H. K. Townes, C. E. Dasch and V. K. Gupta during 1976-1992. Only about 20 of them are **precinctive** and 4-5 are adventive (**immigrants**). Several additional species were discovered during surveys in 1982-1986, and my estimate of species occurring in Florida is about 500-600. In the groups studied so far, about 30 new species have been identified but not yet described. It is difficult to say whether these new species are **precinctive**, and the likelihood is that most have a wider distribution, mainly in adjoining states. Several species occurring in Florida also occur in Central America.

Aphelinids (Hymenoptera: Aphelinidae)

Gregory Evans, Entomology & Nematology Department, University of Florida, Gainesville, FL 32611-0620, USA

Worldwide, the family Aphelinidae contains about 1,120 species in 40 genera. About 42 species in 11 genera are reported from Florida. Of these 42, at least 11 were introduced as biological control agents for homopterous pests, and there is one **immigrant**, leaving perhaps 30 indigenous species. Of these 30, only 3 are reported to occur only in Florida. Most aphelinid species are closely associated with aphid, scale insect, or whitefly host species, many of which have hitchhiked around the world in ships, and later in planes, since the time of Columbus. Knowledge of North American aphelinids is very poor. Knowledge of Florida species has expanded recently because of surveys of parasitoids of *Bemisia tabaci* (Gennadius) and of diaspine scales, but much remains to be done, and an accurate estimate of the number of species is impossible.

Ants (Hymenoptera: Formicidae)

Mark A. Deyrup, Archbold Biological Station, P.O. Box 2057, Lake Placid, FL 33852, USA

There are 149 indigenous species of ants known from Florida (74.2% of the entire fauna). This figure is based on 11 years of survey work, and is not expected to change by more than 10 species. This number includes 14 apparently **precinctive** species, and 135 **indigenous but not precinctive species**. The remaining 52 species (25.8% of the fauna) are **immigrants**. The most secure precinctives are a group of 5 species found in xeric uplands in the central peninsula. Eight apparent precinctives might occur to the north of Florida, and one might be West Indian. Relative to Florida, the other intensively studied southeastern state (North Carolina) has a similar number of indigenous species (145), but these are a larger percent of the fauna (97.0%), and there is only one precinctive species.

Discussion

Our estimate of the total number of insect species in Florida is made roughly, but should be approximately correct. The proportions of species in the subcategory **introduced** should be accurate. The proportions in the other 3 subcategories, **precinctive**, **indigenous but not precinctive**, **immigrant**, are based on the sample shown in Table 1 and should be approximately correct: we have no reason to think the sample is badly biased. We hope that anyone with better methods for deriving estimates will challenge us and publish them. Overall, we estimate that precinctive species are about 13% of the indigenous insect species, and about 12% of the total insect species, in Florida (Table 2). If the estimate of 12,500 insect species in Florida is accepted, and knowing that 42 introduced species have become established, then the proportions and numbers in the other subcategories must be approximately as in Table 2.

The differences between the entomofaunal compositions of Florida and Hawaii are striking (Table 2). Almost all (98.4%) of the Hawaiian indigenous fauna is precinctive, whereas only about 13% of the indigenous Florida fauna is precinctive. At least part of the explanation for this difference is the extreme isolation of Hawaii, but other abiotic and biotic attributes of the Hawaiian environment also may have contributed (see Mooney & Drake 1986). A much greater proportion (33.5%) of the Hawaiian fauna than of the Florida fauna (7.9%) also is adventive, despite the greater isolation of Hawaii. This difference, because it is calculated as a proportion, is accentuated by the relatively smaller size of the indigenous Hawaiian fauna. Nevertheless, Hawaii has a

TABLE 2. A COMPARISON OF THE INSECT FAUNAS OF FLORIDA AND HAWAII.

	Florida		Hawaii[1]	
	Number	Percent	Number	Percent
Indigenous species	**11,512[5]**	**92.1[4]**	**5,059**	**66.5**
Precinctive species	1,514[5]	12.1[4]	4,980	65.5
Indigenous but not precinctive species	9,998[5]	80.0[4]	79	1.0
Adventive species	**988[5]**	**7.9[4]**	**2,549**	**33.5**
Immigrant species	946[5]	7.6[4]	2,137	28.1
Introduced species	42	0.3[3]	412	5.4
Total species	**12,500[2]**	**100**	**7,608**	**100**

[1]The numbers for Hawaii are based on number of species now recorded (from Nishida 1994). [2]estimates of the total number existing, and [3]consequences of these estimates. It is not necessarily true that more species occur in Florida than in Hawaii. [4]estimates derived from Table 1, and [5]consequences of these estimates.

much greater burden of immigrant species (at least 2,137 vs. about 946). The ratio of immigrant to indigenous species in Florida, based on our estimates, is about 1:12, while in Hawaii the ratio is about 1: 2.5 (Table 2). The immigrants to Hawaii are likely, even more so than immigrants to Florida, to be mainly stowaways in cargoes, because the barrier of distance precludes much aerial dispersal and rafting. This is not to say that aerial dispersal and rafting did not occur: they must have been the methods used by the insects ancestral to the present indigenous population (350-400 species; US Congress 1993). We assume that most of the insects introduced into Hawaii were introduced for purposes of biological control, as is true of Florida. Their number in Hawaii is exaggerated by including (apparently) all the species released, whereas we include for Florida only those species known to have become established. The high percentages of adventive species in Hawaii (33.5%) and Florida (7.9%) are strikingly greater than the 1.7% estimated for the contiguous states of the USA (Sailer 1978), and likely for most of those states individually (US Congress 1993).

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THE FIRST COMMERCIAL BUTTERFLY FARM AND PUBLIC EXHIBITION IN THE UNITED STATES

RONALD BOENDER
Founder, Butterfly World Ltd., 3600 West Sample Road,
Coconut Creek, FL 33073-4400

ABSTRACT

Butterfly World rears and displays at any time up to 60 species of butterflies, from 5 continents. The two areas of Butterfly World (farming and public exhibition) have four or five levels of containment. These are designed to prevent escape of the butterflies and their larvae, whose presence in nature might damage horticultural or agricultural plants.

Key Words: Florida, butterfly, native, exotic

RESUMEN

Butterfly World ("El Mundo de las Mariposas") cria y mantiene en exhibición permanente, cerca de 60 especies de mariposas de cinco continentes. Las dos areas, de crianza y de exhibición, cuentan con cuatro o cinco niveles de aislamiento desigñadas para impedir la salida de las mariposas y sus larvas al exterior, donde pudieran producir algun daño a la horticultura o agricultura.

Butterfly World displays a minimum of 2,500 butterflies at all times. During each year about 150 species are housed, and at any time up to 60 species, from 5 continents, are on display. Butterflies are imported and reared, and some are exported. Butterfly World, like other zoological gardens, has several roles. The obvious ones are entertainment and education of the public. The less obvious ones are research into rearing methods, and supply of living specimens to researchers at universities. A potential role is restocking of endangered species of butterflies to their native lands, once the environmental disruptions that caused endangerment are rectified.

However, caterpillars (the larvae of butterflies and moths) are phytophagous, and therefore are classified under federal law and state law as "plant pests." Importation of "plant pests" into the USA is regulated by USDA-APHIS, and importation of all arthropods into Florida is regulated by FDACS-DPI. These laws are designed to prevent the escape into nature of non-native "plant pests" (federal laws) and non-native arthropods in general (Florida law).

The federal and state agencies permit importation of butterflies into escape-proofed holding facilities. Here, I explain how Butterfly World complies with the requirements suggested by federal and state officials. Federal and state concerns are expressed by Firko (1994) and Thomas (this symposium).

BUTTERFLY FARMING

Butterflies in nature are attacked at all 4 life stages by parasites, predators, and pathogens. Farming butterflies requires many methods of protection from, and prevention of these, natural enemies. I will deal only with containment from escape in this symposium, even though some of the following safeguards and construction evolved from the need to protect the butterflies from natural enemies.

Our buildings, laboratory, outdoor rearing areas, and flight areas, were designed and constructed to ensure that butterflies could not escape from their containment, either as caterpillars or as adults. Planning resulted from a partnership with Clive Farrell, owner of the London Butterfly House (England), and the design was created by James Gardner (of England). Butterfly World opened in 1988, and it has an advisory board of biologists.

Butterfly larvae are raised both indoors and outdoors depending on species and food-plant preference. Most are reared from egg to adult indoors. A laboratory is constructed in the inner part of the building, with hallways leading to the outside and a minimum of two doors to the outdoors. All walls and floors are kept spotless and are cleaned daily. All eggs and larvae are kept in special rearing containers which are sealed for the entire egg and larval period. The larvae raised outdoors are held in 183 × 183 × 244 cm (6' × 6' × 8') screened, enclosed cubicles. The base of each door is equipped with a rubber sweep. For a larva to escape to the wild, it would have to crawl through 5 doors, a series of hallways, and a distance of about 46 m (150').

The general public has no access to the larval-growth areas. Any special visitors allowed into these areas must be accompanied by laboratory personnel. All plants removed from the larval-growth areas are placed in a screen-enclosed nursery with a 2-door vestibule-like entry/exit. If any larvae or pupae were left on the plants, they would hatch in this enclosed environment.

The adult butterflies in the breeding areas are likewise kept in 183 × 183 × 244 cm cubicles. To escape, they first must get through the door of their cubicle, which puts them in a narrow hallway and very visible. From the hallway, they must get through two more doors to enter a protected screened nursery which has two more doors with vestibule to the outdoors.

Exhibition

The public exhibition areas are designed to contain adult butterflies for public viewing. The only egg-laying females or larvae allowed in these areas are of native species for educational purposes. Host plants for non-native species are not kept in the public areas. The general public has one entrance and one exit to the exhibition areas. The entrance requires passage through two doors, a long indoor hallway, and a high velocity blower. Butterflies cannot orient indoors without polarized light, so the two doors, hallway, and blower provide four levels of protection. At the exit, the public is reminded to check clothing for hitchhikers, then must pass through a set of doors, a set of plastic strips, a high velocity blower, and another set of doors. These give five levels of protection.

There are three openings to the public exhibition for workers from the laboratory or horticulture. Each opening consists of a two-door vestibule which opens into screened nurseries which again have two-door vestibules to the outdoors.

The grounds surrounding the public exhibition are planted with thousands of nectar-bearing plants (upon which adult butterflies might feed) and host-plants (upon which female butterflies might oviposit). This is designed to attract and retain any escapees.

Conclusion

The two areas of Butterfly World (public exhibition and farming) have four or five levels of containment. These are designed to prevent escape of the butterflies, whose presence in nature might damage horticultural or agricultural plants. The safeguards to escape have been refined since opening of Butterfly World in 1988.

In reality, few species of butterflies pose a threat to agriculture or horticulture. Among non-native butterflies which have become important pests in the USA are *Pieris rapae* (L.) [called "small white" in England, and "imported cabbageworm" in the USA including Florida, though Gerberg & Arnett (1989) call it "European cabbage butterfly"]. Its close relative *Pieris brassicae* (L.) [called "large white" in England, and "European cabbageworm" in the USA] has not yet colonized the USA and is a prime example of a butterfly species whose arrival would harm agriculture. It was against *P. rapae* that the first biological control project in the USA was attempted (Van Den Bosch et al.1982).

Even native species of butterflies can be harmful to horticultural and agricultural plants. The atala butterfly (*Eumaeus atala* Poey subspecies *florida* Roeber) was considered virtually extinct in Florida from the late 1950s, but was reintroduced from a surviving population on Key Biscayne, and by the end of the 1970s was again widespread (Emmel 1991). Its larvae eat leaves of native and introduced species of *Zamia* (Cycadales), which have ornamental value, so the butterfly larvae may be considered to be pests. Larvae of *Dione vanillae* (L.) subspecies *nigrior* Michener (the gulf fritillary) feed on leaves of *Passiflora* spp., and those of various skipper butterflies feed on leaves of *Canna* spp. and bean plants, and are pests to those who try to grow these plants. It becomes a question of whether the grower of plants is willing to sacrifice damage to the plants in return for the pleasure awarded by the sight of the butterflies.

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INVERTEBRATE PETS AND THE FLORIDA DEPARTMENT OF AGRICULTURE AND CONSUMER SERVICES

MICHAEL C. THOMAS
Division of Plant Industry, Florida Department of Agriculture and Consumer Services
P.O. Box 147100, Gainesville, FL 32614-7100

ABSTRACT

The Division of Plant Industry (DPI) of the Florida Department of Agriculture and Consumer Services now regulates importation into Florida of all arthropods except Crustacea, no longer just those of actual or potential agricultural importance. The operating law is Chapter 581.083 of the Florida Statutes, and the operating procedure is Title 5B-57.004 of the Florida Administrative Code. The current law was proposed because of importation by the pet trade of species that did not already occur in Florida and were potentially harmful to the environment. The Division requires specimens (for confirmation of identification) to accompany applications for permits.

Key Words: Exotic species, introduction, Florida, permits, insects

RESUMEN

La División de la Industria de los Vegetales (DPI) del Departamento de Agricultura y Servicios al Consumidor de la Florida, ahora regula la importación a la Florida de todos los artrópodos (excepto crustáceos) y no únicamente de aquellos con importancia real o potencial para la agricultura. La ley es el Capítulo 581.083 de los Estatutos de la Florida, y el procedimiento operativo es el Título 5B-57.004 del Código Administrativo de la Florida. La ley actual fué propuesta debido a la importación por los comerciantes de mascotas de especies que no existen naturalmente en Florida y que potentialmente pueden ser dañinas al medioambiente. La División requiere que las solicitudes de permisos sean acompañnadas por especímenes (para confirmar la identificación).

For the pet industry the days of "how much is that doggy in the window" are long gone. Now it's "how much is that tarantula in the window", and the one with the waggly tail may very well be a scorpion.

In the ever-increasing search for novelty, more and more exotic invertebrates are being offered for sale in pet stores. A perusal of price lists from pet suppliers reveals tarantulas, scorpions and solpugids, whip scorpions and wolf spiders, centipedes and millipedes, mantids and walking sticks, spider wasps and velvet ants, dung beetles and blister beetles that originate from 4 continents, Africa, Asia, Central America, and South America. There are 108 species of tarantulas alone in the pet trade.

In most of the continental United States, these tropical arthropods are relatively benign curios, but in Florida—especially subtropical south Florida—they may pose unknown agricultural or environmental hazards. This brings such exotic arthropods directly under the purview of the Florida Department of Agriculture and Consumer Services (hereafter referred to as department).

For plants and vertebrates the proportion of exotics in south Florida is alarming (Ewel 1986). The invertebrates are much more poorly known, but Frank & McCoy

(1992) listed 271 immigrant species of insects reported from Florida in a 20-year period. For this reason, the Division of Plant Industry of the department now regulates the importation of all arthropods and other possible invertebrate plant pests into the state. This seems to be an unprecedented step by a state department of agriculture. Although the department has regulated the importation of plant pests and parasitoids of plant pests for years, mostly for research or biological control purposes (Denmark & Porter 1973), the regulation of the pet trade in arthropods is a whole new ballgame, and policies and procedures are still evolving as the department gains experience.

HISTORY

The story begins on 30 May 1989 with a newspaper article in the Tampa Tribune (Chen 1989a). The cute feature article reported on a Tampa pet store selling Madagascan hissing cockroaches (*Gromphadorhina* sp.) for pets (Fig. 1). The pet store had sold six of the roaches for $6.00 a piece. The news story had two results: first, the pet store was inundated by telephone calls from people wanting to buy a roach; second, the Commissioner of Agriculture's office was receiving calls from people wanting to know how roaches could be sold as pets in Florida, a state renowned for its roach problems (Chen 1989b).

Some quick telephone calls found that neither the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) nor the U.S. Public Health Service was interested in the Madagascan hissing cockroach. Concerned over the possibility that yet another roach might be added to the state's non-native roach fauna, and acting under its general statutory authority, the department issued a stop sale order to the pet store two days after the first newspaper story appeared (Chen 1989b). In the meantime, the pet store had sold the remaining six roaches it had in stock. Four of the roaches were sold to an unidentified man who released them in his back yard because he was afraid the department would hurt them (Chen 1989c). All of this, of course, was followed gleefully in the press. The publicity seemed to fuel the popularity of the roaches and the next thing we knew a pet store in Miami was selling the former $6.00 Madagascan hissing cockroaches for $19.95. The roaches were confiscated by department inspectors (United Press International 1989).

Several things became apparent during this time. The new attention on the pet trade revealed that the Madagascan hissing cockroach was literally just the tip of an arthropod iceberg hiding in pet stores around the state. Many exotic arthropods were being imported and sold as either pets or pet food. Although several Federal and state statutes apply to plant-feeding or disease-vectoring insects, there were gaping loopholes that allowed such things as roaches and spiders to be imported and distributed with virtually no regulation.

It is well known that Florida, particularly south Florida, is especially vulnerable to the establishment of exotic organisms (Ewel 1986). The pet trade is responsible for many of those problems, and certain aquarium plants are now prohibited from being sold in Florida. The Florida Game & Fresh Water Fish Commission regularly inspects pet stores and is responsible for issuing permits for the sale of exotic vertebrates. The question naturally arose: Is there an arthropod equivalent of melaleuca, walking catfish, or cane toad being sold in pet stores?

The department's enabling legislation, which authorizes the regulation of plant pests and parasites of plant pests, was not adequate for this problem. In January 1990, House Bill 2163 was introduced to amend Chapter 581.083 of the Florida Statutes. It passed on 29 May and became effective on 1 October. The amendment[1] and

Rule 5B-57[2] give the department the authority to regulate any arthropod (with the exception of crustaceans) and require a permit to import into the state or distribute any arthropod that may pose a threat to the agricultural industry or to the environment.

Current Situation

The department has now had more than a year of experience with the new procedure, and the arthropod iceberg seems to be getting bigger and bigger. With some exceptions, the department has concentrated on regulating suppliers and breeders rather than individual pet stores. Department inspectors visited pet stores informing owners of the new regulations and gathering addresses of suppliers who were contacted and notified of the new requirements.

The Florida Game & Fresh Water Fish Commission, whose personnel regularly inspect pet stores, has been reluctant to expand its inspections to cover invertebrates, but it did supply the department with a list of 3700 businesses and individuals in Florida permitted by the Commission to have and sell exotic vertebrates. This list was the basis of an informational mailing. In the past year, over 70 permit applications were submitted for invertebrate pets; most of those came in the two months following the informational mailing.

Permit applications come from zoos, museums, and schools, as well as from distributors, breeders, and pet stores. For the most part, permits are handled on a case-by-case basis, and the proposed use of the organism plays an important part in the decision-making process. For example, a permit is much more likely to be issued for a zoo or museum exhibit than for retail sale. Several criteria are considered in reaching a recommendation. The organism should not be a threat to the state's agricultural industry. It should not be a threat to the public health. If it is likely to become established under Florida climatic conditions, it should not compete with native species.

Based on these criteria, there are certain organisms that either would not be permitted or would be permitted under very tight restrictions. Among these are: plant-feeding terrestrial snails (we are regularly contacted by people wanting to farm brown garden snails); all cockroaches; scorpions of the family Buthidae; stick insects and grasshoppers; all millipedes. Desert tarantulas are not considered a problem, but the genera *Avicularia* and *Phormictopus,* which contain arboreal species, are restricted. The house cricket, *Acheta domesticus,* has been sold as fish bait and reptile food for

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[1]Florida Statutes 581.083. Introduction or release of plant pests, noxious weeds, or organisms affecting plant life. —The introduction into or release within this state of any plant pest, noxious weed, or genetically engineered plant or plant pest, or any other organism which may directly or indirectly affect the plant life of this state as an injurious pest, parasite, or predator of other organisms, or any arthropod, is prohibited, except under special permit issued by the department through the division, which shall be the sole issuing agency for such special permits. Except for research projects approved by the department, no permit for any parasitic organism shall be issued unless the department has determined that the parasite, predator, or biological control agent is a target organism or plant specific and not likely to become a pest of plants or other beneficial organism. The department may rely on the findings of the Department of Natural Resources and the United States Department of Agriculture in making any determination about organisms used for the biological control of aquatic plants.

[2]Florida Administrative Code 5B-57.004 Possession or Movement of Arthropods, Plant Pests, or Noxious Weeds Regulated by the Department.

(1) It is unlawful to introduce, possess, move, or release any arthropod or noxious weed regulated by the department except under permit issued by the department. No permit shall be issued unless the department has determined that the arthropod or noxious weed can be contained to prevent escape into the environment or that it will not pose a threat to agriculture, beneficial organisms, or the environment or become a public nuisance...

Fig. 1. Madagascan hissing roaches sold by pet stores. Photo courtesy of Associated Press Photos.

decades; it has not become established in the wild in Florida and is not considered a problem. Generally, exotic insects, even pest species, are permitted if they are already established in the state.

Procedures

Arthropods falling under the jurisdiction of the USDA must obtain a USDA/APHIS PPQ form 526, which is sent to Hyattsville, MD with the department's recommendation either to approve or disapprove. Arthropods not falling under the jurisdiction of the USDA are covered under the department's PI-208 permit, which is handled in Gainesville. All permit applications must be submitted with voucher specimens of the species to be imported. As I will discuss later, this is an important step since one of the most frequent problems encountered is misidentification by the applicant. The final decision on approval is made by the division's assistant director, acting on the recommendation from the technical sections in the Bureau of Entomology, Nematology, and Plant Pathology.

Specific Cases

The potential hazards of invertebrate pets are not entirely theoretical. In the 1960s, a Miami family carried two giant African snails (*Achatina fulica* Bowditch) home with them as pets from a trip to Hawaii. Eventually they tired of the snails and released them in their back yard. It took a million-dollar campaign by the department to eradicate the resulting infestation. Just recently, a pet store in Tallahassee was discovered to have another, related giant African snail (*Archachatina marginata* (Swainson)) for sale. The supplier was identified and through the supplier several other Florida pet stores were found to be carrying the snail in stock.

In another case, five specimens of a giant Neotropical grasshopper (*Tropidacris c. cristata* (L.)) were collected over a period of about a month in 1992 in a small area in Broward County. How the grasshoppers arrived in central Broward County has never been determined, but since this is one of the largest and most spectacular grasshoppers in the world, it was suspected that they were escapees from a shipment destined for sale in the pet trade.

To illustrate the potential problems inherent in the unregulated trade of exotic invertebrates, I will discuss three specific cases with which the department has dealt since the new rules became effective.

Blaberus roaches. The New World genus *Blaberus* contains several species of very large roaches that are popular in zoo and educational displays, and, it turns out, as reptile food. Two species, *Blaberus craniifer* Burmeister, the Cuban death's head cockroach, and *Blaberus discoidalis* Serville occur in extreme south Florida. Whether they are native, are the result of natural dispersal, or were hitchhikers in cargoes is open to debate, but both are widely distributed in the Caribbean and may be considered a natural component of the Florida Keys fauna (Atkinson et al. 1990). A Tampa zoo requested permission to maintain its colony of *Blaberus giganteus* (L.), which were being used as reptile food and which originally had been obtained from a well-known biological supply house. Examination of voucher specimens from the zoo revealed that the species in question was neither *Blaberus giganteus* nor *Blaberus craniifer*. Instead it was most similar to an unidentified species of *Blaberus* from Ecuador in the Florida State Collection of Arthropods. In this case we reached a compromise by which the zoo destroyed its colony of exotic roaches and the department supplied specimens of *Blaberus craniifer* to start a new culture. By the way, *Blaberus giganteus* is attracted to light. If central Florida residents are upset at the appearance at their lights of the Asian cockroach (*Blattella asahinai* Mizokubo), think of their reaction to the arrival of a cockroach the size of a small bird.

Zophobas beetles. Many pet stores carry giant mealworms. These are the larvae of a large darkling beetle that are popular as food for pet birds and especially lizards. They are also sold as fish bait. They are said by suppliers to belong to the species *Zophobas morio* (Fabricius), which has been listed from south Florida and which is well represented in the Florida Collection of Arthropods with specimens from the lower Keys. Specimens of this genus are virtually unidentifiable, but according to Charles Triplehorn (Museum of Biological Diversity, Columbus, OH) the proper name of the

Florida species seems to be *Zophobas rugiceps* Kirsch, which is widely distributed in the Caribbean. Unfortunately, the species being sold is not conspecific with the Florida examples and may have originated in Central or South America. The department has in the past denied permits to suppliers to import this beetle but, as it is easy to culture, many pet stores and individuals have their own breeding colonies. Its pest potential is unknown but it is related to several stored-products pests.

Chilecomadia moths. "Butterworms" are advertised by the distributor as "the softest worm" and are sold as reptile food in the United States and Europe. In his permit application, the importer spelled the scientific name incorrectly, did not know the family, claimed the larvae were found under rocks in Chile, and that they would immediately die if removed from refrigeration. Eventually, butterworms turned out to be the caterpillars of a Chilean cossid moth, *Chilecomadia morrei* Silva Figueroa. Removed from refrigeration, they lived at least three weeks and fed readily on artificial diet. Cossids are wood-borers as larvae, and recorded hosts for this species in Chile include willows. A related Chilean species is recorded from willow, acacia, and apple. The permit was denied.

CONCLUSION

There is no doubt that invertebrate pets are growing in popularity and that they pose a real threat to Florida's agriculture and environment. Efforts by the Florida Department of Agriculture and Consumer Services to regulate the importation into the state of exotic arthropods and other possibly harmful invertebrates will minimize, but hardly eliminate, the hazards.

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BIOLOGICAL INVASIONS: STEMMING THE TIDE IN FLORIDA

TED D. CENTER[1], J. HOWARD FRANK[2], AND F. ALLEN DRAY, JR.[3]
[1]USDA, ARS, Aquatic Weed Control Research Laboratory, 3205 College Ave.,
Fort Lauderdale, FL 33314

[2]University of Florida, Department of Entomology and Nematology,
Gainesville, FL 32611-0620

[3]University of Florida, Fort Lauderdale Research and Education Center,
3205 College Ave., Fort Lauderdale, FL 33314

ABSTRACT

Invasive, adventive species present a significant challenge to environmental resource managers. Unless this problem is addressed, natural areas face loss of biodiversity and habitat integrity. Traditional control methods are often inappropriate or impractical for use in natural areas. Strategies using biological control, a discipline of applied ecology, offer the best hope for reducing deleterious impacts of invaders. Arguments by some ecologists that classical biological controls contribute to the problem appear unwarranted. These criticisms should not be dismissed out of hand, however. Instead, they should foster in biocontrol scientists a renewed dedication to the safe practice of their discipline and an increased concern for collateral impacts of released organisms on native species.

Key Words: Biological control, invasive species, weeds, insects, Florida

RESUMEN

Las especies adventivas e invasoras presentan un desafío significativo para los administradores de recursos ambientales. A no ser que este problema sea considerado, las áreas naturales encaran pérdidas en la biodiversidad y en la integridad del medio ambiente. Los métodos tradicionales de control son frecuentemente inapropiados o imprácticos para ser usados en áreas naturales. Las estrategias que usan control biológico, lo cual es una disciplina de la ecología aplicada, ofrecen la mayor esperanza para reducir los impactos dañinos de los invasores. Los argumentos de algunos ecólogos de que el control biológico clásico contribuye al problema parecen ser injustificados. Sin embargo estas críticas no deben de ser desechadas de inmediato. En su lugar deben de alentar en el científico dedicado al control biológico una renovada decidicación a la práctica segura de su disciplina y un aumento en su preocupación por los impactos paralelos de los organismos liberados en las especies naturales.

Environmentalists and conservationists have often failed to appreciate the threat posed by invasive, adventive species to biodiversity in natural areas (see, for example, Soulé & Wilcox 1980). In recent years, however, the impact of exotic organisms on biological communities, particularly in natural areas, has become a compelling environmental issue (McKnight 1993). This is particularly true in Florida and a briefing document for the state legislature has recently been prepared on this subject by a delegation of experts assembled by the Florida Department of Environmental Protection. The best documented cases are those evolving from purposeful importations of non-indigenous plants. The magnitude of this problem cannot be exaggerated. About 456 million exotic plants were imported through the 16 U.S. plant introduction facilities during 1993, with nearly 80% of these coming through the port of Miami (pers. comm. - D. R. Thompson, Operations Officer, USDA-APHIS Port Operation, Hyattsville, MD). These imported plants represent a huge pool of potential invaders, directly through their own escape and naturalization, and indirectly through the insects and other pests that they might harbor.

The number of organisms imported for biological control purposes pales in comparison, yet biocontrol is increasingly being identified as contributing to the problem rather than proffering a cure (Howarth 1983, Simberloff 1992). This viewpoint represents more concern for the “mole hill” than for the “mountain”. Still, the concerns expressed are not altogether unwarranted. It would behoove biological control practitioners, therefore, to take a proactive stance in order to ensure that biological control does not come to be regarded as an ecological pariah.

THE PROBLEM

Introduced and immigrant plant species represent a severe challenge for conservationists. Those that successfully invade natural areas may outcompete native species and develop extensive monocultures. These monocultures not only exclude native ecological homologs, but frequently also exclude many associated species. In extreme cases, such invasions can convert a healthy, diverse biological community into a barren monoculture.

The susceptibility of pristine areas to invasion by exotic species is partially related to disturbance and the size of reserves. Disturbed edge habitats presumably function as staging areas from which exotic species invade the surrounding landscape. Other things being equal (see Londsdale 1992), smaller areas with proportionately more edge habitat are more susceptible to invasions than large contiguous conservation areas (see Ewel 1986 for other theories). This suggests that the establishment of large reserves might impede invasions by exotics. However, vast size alone does not preclude problems. Perhaps the best example of a large preserve is Kakadu National Park (13,000 km^2) and adjacent aboriginal reserves in Australia’s Northern Territory. Together, these comprise one of the world’s largest protected natural areas which encompasses the entire Alligator River drainage basin. Yet, the pristine nature of this area is threatened by invasions of adventive species. The weedy legume *Mimosa pellita* Humb. & Bonpl. ex. Willd. (=*M. pigra* L.) now occupies 450 km^2 of seasonally inundated floodplain in nearby areas. The establishment of this species was facilitated by yet another adventive species, the water buffalo (*Bubalus bubalis*), which trampled the floodplains, thereby creating disturbed habitat. These buffalo also browsed competing vegetation. *M. pellita* has now effectively transformed a wide range of structural vegetation types to homogenous tall shrublands, thus causing disastrous consequences to wildlife (Beckman 1990, Londsdale & Braithwaite 1988; Braithwaite et al. 1989). This plant also blocks river and wetland access to local fauna while the floating fern *Salvinia molesta* Mitchell impedes access to seasonal ponds (billabongs). These freshwater habitats are the principal source of water for wildlife during the long dry season, so this transformation has far-reaching impacts. Furthermore, African grasses which are taller with deeper root systems than native species, fuel hotter fires later in the dry season than those typically carried by native grasses. These hotter fires destroy the otherwise fire-resistant sclerophyllous woodlands (Breeden & Wright 1989). Hence, invasive exotic plants are degrading aquatic and upland habitats alike.

Ecological complexity has also been linked to the susceptibility of natural communities to invasions, species-rich communities supposedly being less susceptible than species-poor ones (Ewel 1986). The fynbos of South Africa is one example where this generalization fails, however. This distinct floral kingdom is perhaps the most diverse non-tropical system on earth, harboring as many as 121 plant species within a 100 m^2 area (van Rensburg, undated). Despite this high diversity, the fynbos is threatened by invasive exotic plant species like *Acacia* spp., *Hakea* spp., *Pinus* spp., *Sesbania punicea* (Cav.) Benth., etc. (Taylor 1978). Likewise, rubber vine (*Cryptostegia grandiflora* R. Br.) from Madagascar grows rampant in subtropical and tropical Queensland, another highly diverse region, covering trees up to 30 m tall and choking out native vegetation (McFadyen & Harvey 1991).

An example of an invasion by an exotic species into a species-rich, relatively undisturbed area is provided by *Salvinia molesta*. This South American native was probably released in New Guinea from aquaria. A few plants wound up in aquatic sites on the Sepik River floodplain in about 1971-72. The plant spread rapidly, with nearly disastrous consequences (Mitchell et al. 1980, Thomas & Room 1986a,b).

Exceptions can be found to most generalizations pertaining to factors contributing to site invasibility. This is because invasibility depends upon characteristics of both the invading species and the habitat being invaded. Thus, a particular site might be very susceptible to invasion by one species but resistant to another. Likewise, a single exotic species might easily invade at one site, but be unsuccessful at another. One factor remains paramount, however. Potential invaders must be available. Proximity and availability of a pool of invasive species is a preeminent factor. This factor is ignored by most ecologists who study biological invasions, being either too obvious or perhaps merely biologically uninteresting.

The main source of potential invaders appears to be the commercial importation of plants. As noted previously, vast numbers of plants are imported to the United States each year. This creates a tremendous pool of potential invaders. Obviously, the more exotic species that are present, and the higher the frequency with which they are imported, the greater the likelihood that one or more will invade natural areas.

Ewel (1986) observed that few mammals or trees have invaded the mature forests of the Amazon basin, New Guinea, or Zaire, as compared to Great Britain or New Zealand. He suggested that high species richness and absence of disturbance insulates these communities from invasion. We suggest that lack of economic incentives for the importation of large quantities of ornamental species also explains much of the disparity. In the case of New Zealand, for instance, active "acclimatization" societies have existed since the colonial period (Booz 1991). These societies were dedicated, until the early 1900s, to the introduction of all plant and animal species that they considered desirable. Hundreds of species were thus imported and released. Many of these invaded natural communities. Were it not for these societies, many of these invasions would never have occurred. Although formal acclimatization societies don't exist in Florida, efforts to introduce non-native species (including plants, fish, birds, reptiles, etc.) have been at least as intensive. Florida's biota now includes over 1300 adventive species (U.S. Congress 1993). To our knowledge, no comparable effort has ever been made to introduce species into the aforementioned Amazon basin, New Guinea, or Zaire.

Examples of commercially imported plants "gone bad" are readily available. The paperbark tree (*Melaleuca quinquenervia* (Cav.) S. T. Blake) in Florida (Bodle et al. 1994, Hofstetter 1991), Chinese tallow tree (*Sapium sebiferum* (L.) Roxb.) in the Southeast (Farnsworth 1988), and purple loosestrife (*Lythrum salicaria* L.) in the northern U.S. (Thompson et al. 1987, Malecki et al. 1993) devastate valuable wetlands. Austin (1978), in fact, reported that *M. quinquenervia* reduces biodiversity by 60-80% when it invades wet prairie or marsh communities. It now occupies an estimated 489,000 acres in southern Florida (pers. comm. - A. Ferriter, South Florida Water Management District, West Palm Beach, FL).

Brazilian peppertree (*Schinus terebinthifolius* Raddi) was reported as being common in cultivation but rare in the wild in southern Florida as recently as 1959 (Austin 1978). It now infests 602,000 acres (pers. comm. - A. Ferriter, South Florida Water Management District, West Palm Beach, FL) in a wide variety of habitats, displacing native vegetation in both upland and wetland communities (Myers & Ewel 1990). Acreages would be considerably higher if estimates from the rest of Florida were available. Australian pine (*Casuarina equisetifolia* J. R. Forst. & G. Forst.) interferes with the nesting activities of sea turtles and American crocodiles in coastal communities (Austin 1978) and infests 373,000 acres in southern Florida (pers. comm. - A. Ferriter, South Florida Water Management District, West Palm Beach, FL). This species is also reported to inhibit growth of native plants and to open beaches and dunes to erosion. Austin further noted that as few as a dozen species typically occur in the understory, most of which are adventive. Brazilian peppertree and Australian pine were both introduced as landscape plants.

Cogongrass (*Imperata cylindrica* (L.) Beauv.) was imported into Florida in the 1940s for erosion control and as a source of forage. It failed to be useful for either purpose and now displaces native plants (Coile & Shilling 1993). Another plant introduced for erosion control in Florida and other portions of the Southeast is the notorious kudzu (*Pueraria lobata* (Willd.) Ohwi) (Baker 1986). Like the madagascarine rubber vine in Australia, it blankets tall trees and smothers native vegetation. Other vines cause similar problems in Florida with the Japanese climbing fern (*Lygodium microphyllum* (Cav.) R. Brown), air potato (*Dioscorea bulbifera* L.), and skunk vine (*Paederia* spp.) being good examples. Austin (1978) recorded *L. microphyllum* populations from several counties in southern Florida, and it has recently been reported to infest 26,000 acres, mostly in Palm Beach and Martin counties (pers. comm. - A. Ferriter, South Florida Water Management District, West Palm Beach, FL).

Aquatic habitats seem particularly vulnerable to invasion. The neotropical floating waterhyacinth (*Eichhornia crassipes* (Mart.) Solms.) blankets open water surfaces of lakes and rivers in Florida as well as most other subtropical and tropical areas of the world. Infestations limit access to fishing areas by indigenous peoples in undeveloped countries, increase habitat for disease vectors, reduce the supply of fresh water available to wildlife, and lower oxygen levels in the submersed community. Drifting mats scour native vegetation and destroy nesting sites and foraging areas for rare species (such as the snail kite in Florida). This plant was introduced to decorate garden ponds. The submersed weed hydrilla (*Hydrilla verticillata* (L.f.) Royle) was introduced through the aquarium trade. It invades aquatic sites by growing from the hydrosoil to the water surface where it forms a thick canopy. The resultant dense beds readily displace other submersed aquatic species. As a result, diverse aquatic communities become monocultures. These often lack phytophagous consumers and harbor less desirable detritivore-based faunal assemblages (e.g., Hansen et al. 1971, Dray et al. 1993).

Imported plants threaten the preservation of “pristine” natural areas in other ways. Exotic insects, many of which attack native plants, are often imported on ornamental plants. A recent study estimated that, as of 1992, 271 exotic insect species have immigrated into the state of Florida during the previous two decades. In contrast, only 151 species have been introduced into Florida for biological control purposes *in the past century*. In 1980 over 18,000 immigrant insects were intercepted by the U.S. Department of Agriculture (APHIS) at ports of entry (Frank & McCoy 1992, 1993). These were mostly transported on imported plants, 99% of which are not inspected.

Some of these immigrants (e.g., the gypsy moth in northern areas) have the capacity to reduce biodiversity in native plant communities. A good example is the cactus moth (*Cactoblastis cactorum* (Bergroth)) in Florida, which was purposely released in the Caribbean region during the 1950s for biological control of *Opuntia* spp. Recent evidence (pers. comm. - R. Pemberton, U.S. Department of Agriculture, Agricultural Research Service, Aquatic Weed Control Laboratory, Fort Lauderdale, FL) suggests that it arrived in Florida within exotic cacti, truckloads of which are routinely imported from the Dominican Republic and Brazil. Once here, it began to attack several species of native cacti (Simberloff 1992), including the endangered semaphore cactus (*Opuntia corallicola* (Small) Werdermann in Backeberg).

The weevil *Metamasius callizona* (Chevrolat) arrived in Florida from Mexico in shipments of exotic bromeliads (O'Brien & Thomas 1990). It now infests *Tillandsia utriculata* L., *T. fasciculata* Sw., and *T. paucifolia* Baker, all native bromeliad species (Frank & Thomas 1994), and has nearly extirpated *T. utriculata* from several southern Florida hammock communities (TDC, pers. obs.). A related weevil *M. hemipterus* (L.), first discovered in Florida in 1984, feeds on a wide range of hosts including bananas, sugarcane, and palms (Woodruff & Baranowski 1985, Giblin-Davis *et al.* 1994). It could jeopardize the few native royal palms (*Roystonea elata* (Bartr.) F. Harper) that remain in southern Florida.

A neotropical leaf beetle (*Neolochmaea dilatipennis* (Jacoby)), discovered near Miami in 1975, feeds on the Florida "endemic" *Borreria terminalis* Small (White 1979). It has also recently wiped out ornamental plantings of the beach creeper, *Ernodia littoralis* Sw. (TDC, pers. obs.), a native coastal species listed as of special concern (Craig 1979). A Central American weevil (*Eubulus trigonalis* Champion), recently discovered in Dade Co., Florida (pers. comm. - J. Peña, University of Florida, Tropical Research and Education Center, Homestead, FL), probably arrived in non-indigenous cycads that were imported for the nursery trade. Unfortunately, it attacks native cycads (*Zamia* spp., commonly known as coontie) which are also "threatened" species.

An adventive tortoise beetle (*Chelymorpha cribraria* (F.)) was discovered in Florida in 1993 which feeds on native morning glories (Duquesnel 1994). The little fire ant (*Wasmannia auropunctata* (Roger)) which arrived on Santa Cruz Island in the Galapagos where it displaced several native ant species including two "endemics" (Höll-dobler & Wilson 1990), also occurs in southern Florida. It is apparently adventive throughout both Old and New World tropics (Creighton 1950). The red imported fire ant (*Solenopsis invicta* Buren) displaced the native fire ant (*S. geminata* (F.)) in Texas, perhaps inducing a restructuring of the entire arthropod community (Porter et al. 1988). This species has been naturalized in Florida for some time now. Many more "biological pollutants" have been discussed in several recent publications (McKnight 1993, Van Driesche 1994, U.S. Congress 1993).

Biological Control as a Possible Solution

Traditional control methods (pesticides, etc.) are useful against these invasive species when they occur at an incipient stage. In these cases, the aim is generally towards eradication. Eradication is most likely when the introduced species is already known to be noxious, it is found early, and funds are readily available for an all out assault. However, most invaders of natural systems are not recognized as problems until they've gotten out of hand (this is especially true of insect pests). By then, it's often too late to realistically expect to eradicate or even to contain them using traditional measures. This is due to the inaccessibility of the habitats, the difficulty of detecting unseen infestations, and the associated expenses involved. The identification of **host-specific** natural enemies from within the native range of the target pest, and their subsequent importation into the pest's adopted range, offers considerable promise as an additional control measure in the arsenal of natural resource managers. Australians are introducing host-specific plant-feeding insects and phytopathogens to control *Mimosa pellita* in the Northern Territory (Forno 1992). South Africans have successfully controlled *Sesbania punicea*, *Acacia longifolia* (Andr.) Willd., and *Hakea sericea* Schrader in the fynbos using highly specific insects that destroy plant reproductive tissues (Dennill & Donnelly 1991, Hoffman & Moran 1991, Kluge & Neser 1991). Populations of *Salvinia molesta* in Australia, New Guinea, Sri Lanka, India, Botswana, and Namibia were reduced by 99% within a year after introduction of the weevil *Cyrtobagous salviniae* Hustache (Thomas & Room 1986, Room 1990, Room et al. 1981). Alligatorweed, a notorious mat-forming aquatic species, has been almost totally controlled in many areas by a flea beetle (*Agasicles hygrophila* Selman & Vogt) and a moth (*Vogtia malloi* Pastrana) (Spencer & Coulson 1976). Waterhyacinth is less of a problem in many parts of the world, including Florida, due to the introduction of biological control agents (Center et al. 1990). Prospects for biological control of purple loosestrife appear promising (Malecki et al. 1993, Hight 1993). All of these biological control agents are highly host specific and none exploit native plants as developmental hosts.

How Does Biocontrol Work?

A common belief is that imported species become problems by being introduced into a new area without the repressive forces (i.e., natural enemies) that held them in check in their native habitats (see Ewel 1986). Under this paradigm, biological control represents a remedial attempt to restore some sort of natural balance. This is an erroneous perspective. Biological control programs do not strive to duplicate the population regulatory processes of a pest organism's native environment. When natural enemies hold a species in check in natural conditions, multiple species, including both specialists and generalists, are involved. Biological control relies on the introduction of only a selected few of these species, most often only specialists judged capable of repressing the pest population. Obviously, as Ewel (1986) notes (using Kudzu, *Pueraria lobata*, as an example), many species are just as invasive in their native range as they are in adventive areas. The organisms that might otherwise repress these species are oftentimes themselves controlled by numerous species of natural enemies. However, when these agents are introduced into new areas for biological control purposes, their natural enemies are excluded. In theory, at least, higher populations are thereby attained in their adopted range thus resulting in better control than in the homeland.

In many cases, biological control agents are sparse in their native range, but become abundant when introduced into their host's adventive range. For example, parasitism and competition prevent the bud-galling wasp *Trichilogaster acaciaelongifoliae* Froggatt from becoming highly abundant on its host *(Acacia longifolia*) in Australia (Neser 1985). Released from these regulators, however, this wasp became an abundant and effective biocontrol agent in South Africa (Dennill 1985). This is just one of many examples that could be cited demonstrating that successful biological control agents are not necessarily effective regulators in their native habitats. Of course, obvious effectiveness in their homeland is always a good sign.

In general, potential biocontrol agents are released into a pest's adventive range only if the possibility for collateral damage to native species is negligible, as demonstrated through intensive host range trials. However, it may at times be prudent to accept modest levels of collateral damage to native species in order to prevent more extreme levels of habitat destruction by an immigrant or introduced pest. Australian government scientists, for example, are introducing plant-feeding insects and phytopathogens from Madagascar to control the aforementioned rubber-vine (McFadyen & Harvey 1991). They released one of the insects, the moth *Euclasta whalleyi* Popescu-Gorj & Constantinescu, with the knowledge that it would also feed on a related native vine, *Gymnanthera nitida* R. Br. They reasoned that the possibility of reducing the abundance of one native species was a small price to pay for the sake of preserving many others.

FUTURE CONSIDERATIONS

Environmental problems caused by adventive species in Florida are among the most severe in the United States (U.S. Congress 1993). Invasive plant species are the most obvious problem, and are particularly easy to track after they achieve nuisance proportions. Populations of introduced vertebrates are also relatively easy to follow. Adventive invertebrates (e.g., insects) are much harder to assess, however. Limited knowledge of many native invertebrates, together with the sheer volume of species present in Florida, make monitoring for effects of adventive species a daunting and expensive proposition. Further, problems with invader species are exacerbated by the increasing pressure on public lands caused by Florida's rapidly growing human population. The Florida Department of Environmental Protection recently assembled a statewide panel of biologists and ecologists to assess these problems and develop recommendations for remedial actions. These recommendations are still pending. However, a few points are already apparent.

If the source of the problem is the wanton introduction of exotic species for economic gain, then the ultimate solution is largely dependent on political processes. The importation of exotic species is economically lucrative, so legislative attempts to regulate this practice are bound to be met by stiff opposition. It is ironic that about the only activity involving the introduction of exotic species (aside from prohibitions against use of plants on the federal noxious weed list) that is routinely subjected to intense scrutiny is the introduction of biological control agents. Just about anyone can introduce anything, provided that their intent is not to use that organism for biological control purposes.

All importations of living organisms should be intensively regulated, but such regulation is unlikely to be implemented in the near term. Inspectors are already unable to meet APHIS' goal for examining 2% of the plants passing through Miami's ports of entry, so increased levels of inspections are unlikely. Restricting importations to seeds might provide some relief, but would be strongly contested. Routine fumigation of all plant shipments might eliminate invertebrate stowaways, but the costs and logistics of such a program would be overwhelming. Public education campaigns encouraging use of native plants and advocating patronage of nurseries providing only native species have yet to be initiated on any substantive scale. In any event, changing consumptive habits of the general populace is a slow process. These realities dictate that we deal with the symptoms of the problem, rather than the cause.

Biological control would seem to offer the best strategy for dealing with these symptoms. Concurrently, integrated control methods must be developed and natural areas must be managed to maintain the integrity and health of native ecosystems. Together, these offer the best hope for dealing with invasive, adventive species. We hasten to add that biological control is not a panacea and that legitimate criticisms should be addressed. The impacts of biological control agents on native species, for example, have often not been appraised during the screening process. Fortunately, this is rapidly changing and possible effects of introduced biological control agents on non-economic native species are now routinely considered.

In order for biological control to develop fully as a pest control alternative, safety must not be compromised. Even one unwise introduction could set all biological control programs back many years, resulting in even greater regulation and slower progress. This places onerous responsibility on each and every biological control scientist. However, the increased demand that we are now experiencing for biological control agents could easily compromise safety. For example, if increased funds become available on a competitive basis and are thinly distributed among many laboratories, the end result might be the creation of many poorly-funded projects. The associated competition and demand for productivity with inadequate funding could force compromises that would not favor safety. A wiser approach would be to develop a few, well-funded projects based at "first-class" facilities so as not to jeopardized objectivity in the reckless pursuit of research dollars (Drea 1993).

The increased demand for biological controls could also result in pressure to develop programs more quickly, thus compromising the care and caution normally employed. Researchers oftentimes perceive (whether justified or not) the potential loss of funds if a biological control candidate that has undergone research for several years must be abandoned. This insecurity could lead to attempts to introduce agents that might not otherwise be considered. This should not be allowed to happen. Researchers should have the security of knowing that their budget will not be affected by these decisions. This again points to the need for adequate and stable funding. The lure of new funding tends to make experts out of dilettantes. This could be problematic if novices begin to introduce biological control agents without following proper protocol (Drea 1993). It might therefore become necessary to develop certification procedures for biological control specialists. Safety still depends on the integrity and honesty of the research scientists, even though the release of a biological control agent is dependent upon review by state and federal agencies.

CONCLUSION

Florida is a major point of entry for non-native species into the United States. Many become permanent residents in Florida, whether by design or by accident. Further, some demonstrate an unfortunate propensity for invading natural areas. These invasive adventive species can reduce biodiversity, thereby challenging efforts to conserve natural areas. Careful, scientific introduction of biological control agents is an appropriate mitigative strategy. The arguments presented by Howarth (1983) that biocontrol agents might be part of the problem, rather than part of the solution, are not convincing (see Lai 1988). More data are needed, though, on unintended effects of **recent** introductions. This issue must be resolved in a manner that avoids the creation of crippling, bureaucratic regulatory institutions. We must proceed with the development of environmentally sound pest management practices to protect the integrity of both natural and agricultural ecosystems in Florida. Classical biological control typically represents a solution that has no market profit, so public funding is required. The recognition of biological control as applied ecology and development of specialized curricula heavily weighted towards ecology in the training of future biological control specialists would help. Also, research leading to the release of new agents should be focused at a few "first-class" facilities and priority projects should be provided with adequate, long-term public funding.

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RESPONSES OF *MACRODACTYLUS* SPP. (COLEOPTERA: SCARABAEIDAE) AND OTHER INSECTS TO FOOD ATTRACTANT IN TLAXCALA AND JALISCO, MEXICO

HUGO CESAR ARREDONDO-BERNAL[1,3], JUAN CIBRIÁN-TOVAR[1] AND ROGER N. WILLIAMS[2]

[1]Centro de Entomología y Acarología Colegio de Postgraduados, 56230 Montecillo, Estado de México

[2]Department of Entomology Ohio Agricultural Research and Development Center The Ohio State University 1680 Madison Avenue, Wooster, OH 44691-4096

[3]Current address: Centro Nacional de Referencia de Control Biológico, Apartado Postal 133, Tecomán, Colima 28130, México

ABSTRACT

The effects of a food attractant [trinary mixture of hexanoic acid, valeric acid and octyl butyrate (1:1:1)] were evaluated in a trapping trial for scarab beetles in the Mexican states of Tlaxcala and Jalisco. This mixture was highly attractive to *Macrodactylus nigripes* Bates in Tlaxcala and *M. murinus* Bates in Jalisco, capturing a mean of 50.2 and 84 individuals per trap per sampling date, respectively. In addition, all other insects which were taken at the traps were identified to family and classified by feeding habits. Only one non-scarabeid species appeared to be attracted to the baited traps, i.e. *Apis mellifera* L.; all other insect families averaged less than one individual per trap.

Key Words: *Macrodactylus nigripes, M. murinus,* semiochemicals, trapping

RESUMEN

Se evaluó el efecto de un atrayente alimentario en la captura de escarabajos en los estados de Tlaxcala y Jalisco, México. El atrayente fue una mezcla de ácido hexanóico, ácido valérico y octil-butirato (1:1:1). Esta mezcla fue altamente atractiva para la captura *Macrodactylus nigripes* Bates en Tlaxcala (un promedio de 50.2 individuos por trampa por muestreo) y para *M. murinus* Bates en Jalisco (un promedio de 84 individuos por trampa por muestreo). Otros insectos capturados fueron identificados a nivel de familia y clasificados de acuerdo a sus hábitos alimentarios; el efecto del atrayente alimentario sobre estas poblaciones fue selectivo.

There are at least 28 known species in the genus *Macrodactylus*, all from the Nearctic region. The 20 species of *Macrodactylus* from Mexico are known as "frailecillos," "taches," or "burros" and feed on a wide variety of cultivated and wild plants (Morón & Terrón 1988). The larvae (grubs) are strictly root feeders. However, the adult stage causes damage to leaves, flower buds and fruits of many cultivated plants (Morón & Terrón 1988; Williams et al. 1990).

In Huamantla, Tlaxcala, and Manantlán, Jalisco, the adults of *Macrodactylus nigripes* Bates and *M. murinus* Bates are important pests of maize (Altieri & Trujillo 1987). The adults emerge after the first rains and appear to be synchronized with the development of the maize crop. *Macrodactylus* spp. consume the pollen in the tassels, thereby reducing pollination. When the infestation is heavy, the beetles also consume the silks (styles), preventing pollination, and thus prohibiting the formation of grain. Insecticides have been widely utilized against this group of insects in Mexico. However, in the Manantlán Biosphere Reserve where pesticides are prohibited, we are searching for an alternate means for control which would be sustainable and environmentally sound.

Many studies have been carried out to determine efficacy of food attractants, e.g., for Japanese beetle, *Popillia japonica* Newman (Fleming 1969). For *Macrodactylus*, the first report of luring adult beetles to feeding attractants was mentioned by Johnson (1940), who collected *Macrodactylus* species at baits designed for Japanese beetles. In 1982, Williams & Miller determined that various aromatic compounds were attractive to adults of *Macrodactylus subspinosus* (F.) in Ohio and that hexanoic acid and valeric acid were the best attractants. Later Williams et al. (1990) conducted a study in which they evaluated more than 60 compounds with the objective of finding the best attractant for monitoring populations of *M. subspinosus*. The results of these studies showed that the mixture of valeric acid, hexanoic acid, and octyl butyrate, in the ratio of 1:1:1 exhibited the best attraction. In Chapingo, Cibrián et al. (1990) observed that this mixture was attractive to *M. mexicanus* Burmeister and various other insects. At the same time, they determined that trap color did not influence the capture of *M. mexicanus*. The objective of the present study was to determine the effects of this same food attractant on the capture of *M. nigripes*, *M. murinus*, and other insect taxa in Huamantla, Tlaxcala, and Manantlán, Jalisco.

Materials and Methods

The attraction of the test mixture on *M. nigripes* in Huamantla, Tlaxcala, was determined with 48 Yellow Super Traps (Reuter Laboratories, Manassas VA) placed in a field of maize known to be infested during the previous seasons. The traps were evenly distributed in an area of the field 0.5 ha in size. The objective was to measure the total capture of "frailecillos" per week. The first captures were based on collections of 16 traps.

At the second location, Manantlán, Jalisco, 36 traps were utilized to determine numbers of *Macrodactylus murinus* caught each fortnight. Traps were distributed uniformly in a maize field which was 0.375 ha in area. At the time the traps were set, the maize was in early florescence.

The traps were hung from galvanized pipes at approximately 1 m above the soil surface. A plastic bag attached to the bottom of each trap served as a receptacle to collect the beetles. Each bag was perforated with tiny holes near the bottom to avoid water accumulation during the rainy season, thus partially avoiding biological decomposition in the bags. Five ml of the volatile mixture of valeric acid, hexanoic acid and octyl butyrate were deposited in small green containers (Loral Poly-Cons) described in Klein & Edwards (1989). These containers were placed in the traps with their openings downward in order to avoid dilution of the attractant by rain or decomposition by direct sunlight.

At the same time, the effect of the trap density (4 or 8 = 64 or 128 per ha) on the capture of *M. nigripes* was determined in 1/16 ha plots in Huamantla, Tlaxcala. Each treatment was replicated four times using randomized blocks. With these parameters, we were able to measure the number of insects captured per trap. Means were compared by t test.

The effect of these attractants on other groups of insects was determined in Tlaxcala by recording the number of captures per trap per week. In Jalisco, the captures were recorded fortnightly. The identification of the majority of insects was made to family and, in some cases, to species.

Results and Discussion

In Huamantla, Tlaxcala, 5,832 *M. nigripes* were collected in 48 traps over a 10 week period. Based on trap captures, the maximum adult response at this location was from July 4 to July 15 (2,295 beetles). Collections decreased after that until the end of the season. However, there was an irregular pattern the week of July 30 - August 6, which was lower than the two adjacent weeks. After September 10, no more beetles were caught (Fig. 1). The differences in the numbers of specimens captured in the week of August 6-13 perhaps was due to a dry period followed by rain which stimulated adult emergence. In some parts of Mexico, adults are active for approximately a four-month period. In Chapingo, Mexico, studies conducted by Cibrián et al. (1990) showed that the capture of *M. mexicanus* is similar to that of *M. nigripes* in Huamantla, Tlaxcala.

In Manantlán, Jalisco, where 36 traps were set, the capture of *M. murinus* over the entire collecting period was 12,102 beetles. The maximum capture was between September 18 and October 2, with 10,613 beetles captured for the period. During the next fortnight, collections decreased by 93% to only 470 beetles. After October 30, no *M. murinus* adults were collected, indicating the end of the adult activity period (Fig. 2).

An average of 50 specimens of *M. nigripes* were captured per trap over the entire experiment, while 84 *M. murinus* were captured per trap. These figures are low com-

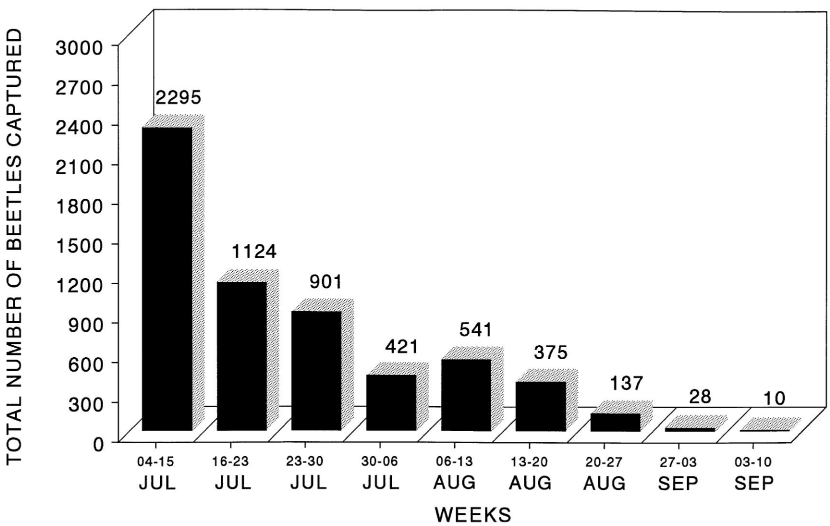

FIG. 1

Fig. 1. Trapping of *Macrodactylus nigripes* Bates with a food attractant in 48 yellow traps, Huamantla, Tlaxcala, Mexico, 1990.

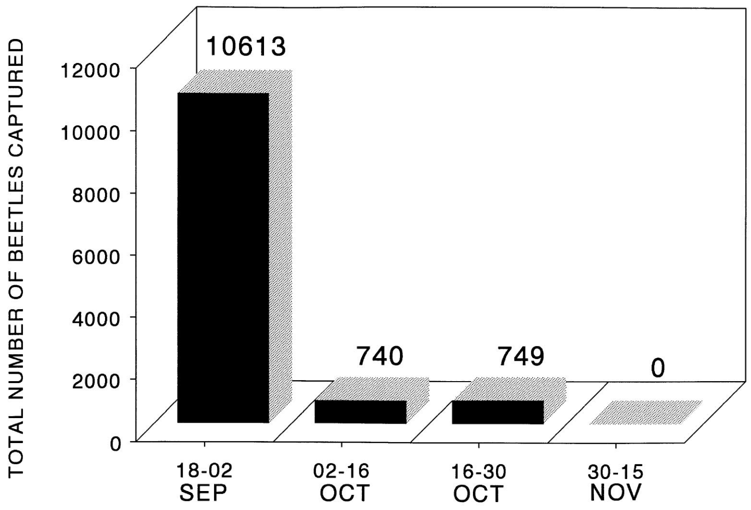

FIG. 2

Fig. 2. Capture of *Macrodactylus murinus* Bates with a food lure in 36 yellow traps, Manantlán, Jalisco, Mexico, 1990. (Fortnightly)

pared to those reported by Williams et al. (1990) with the same attractant in Ohio where 125 *M. subspinosus* were captured per trap. Of course, these collections can not be directly compared but are mentioned here as a reference to the abundance of *Macrodactylus* spp. when present. Here, we are dealing with different species, thus trap catches may reflect the degree of efficacy in response to attractant rather than population density.

Because maize was the major host being considered in this study, it would seem that *Macrodactylus* spp. may have built up to higher numbers due to the extended flowering period in which the maize plant is vulnerable. The flowering period of maize is locally extensive because the maize is planted over an elevation gradient of more than 500 m and the maize flowers at different times, depending upon the elevation.

Having studied the collection and behavior of the populations, it was determined that the use of feeding attractants is a viable option for monitoring *Macrodactylus* adult activity. However, when the traps and attractants are used experimentally, it is necessary to correlate the number of insects captured with the density required to cause damage (economic threshold). This information might aid in a better understanding of the degree of protection offered by trapping the beetles.

The capture of beetles using two different trap densities was compared on populations of *M. nigripes* in parcels of 1/16 ha. It was determined that the higher density of traps captured significantly ($t = 3.77$, $P = 0.05$) greater numbers of beetles. Fig. 3 shows the differences in the numbers of beetles which were captured on different dates of the experiment. Effects of trap densities were observed on local populations of *Macrodactylus* spp. where correlated studies were conducted with differing numbers of traps, insects captured and numbers of these insects.

The results indicate that the food lure in these trials could be used for behavioral studies of the two species of *Macrodactylus*.

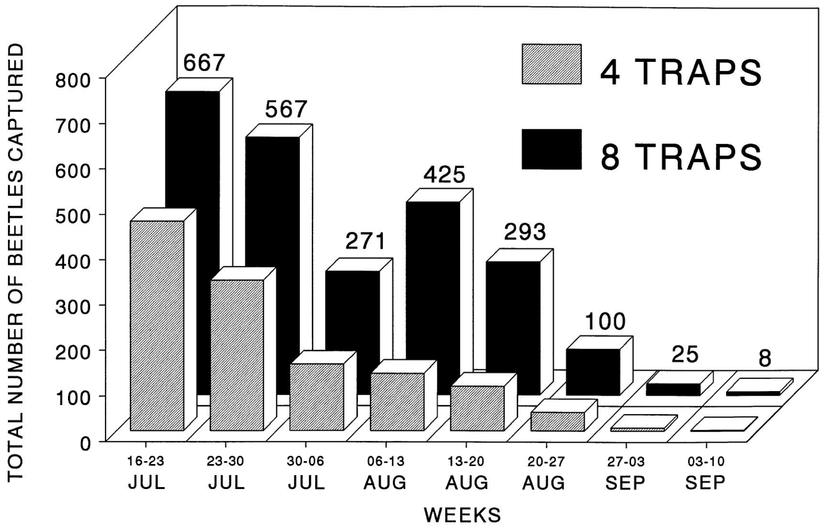

FIG. 3

Fig. 3. Response of *Macrodactylus nigripes* Bates to a food attractant using trap densities of 4 and 8 traps in 1/16 ha, Huamantla, Tlaxcala, Mexico, 1990.

Specimens of other insect groups trapped include a variety of families with diverse feeding habits. Interestingly, the phytophagous insect caught in greatest quantities was another scarab, "mayate de la calabaza," *Euphoria basalis* Burmeister. An average of 0.38 *E. basalis* beetles were collected per week per trap. Cibrián et al. (1990) captured similar numbers of *E. basalis* in Chapingo. Other phytophagous families collected in descending order included Mordellidae, Elateridae, Meloidae, Scarabaeidae (other than *Macrodactylus* and *Euphoria*), Curculionidae, Noctuidae, Nitidulidae, Chrysomelidae, Miridae, Tenebrionidae, Pentatomidae, Lygaeidae, Anthicidae, Cerambycidae, Tephritidae, Cicadellidae, and Coreidae.

Of the insect predators captured, Cleridae were caught in the greatest numbers (0.96 beetles per trap per week). Insects from other predaceous families were captured less frequently (less than 0.107 beetles per trap per week). The major families collected were: Thomisidae, Histeridae, Coccinellidae, Staphylinidae, Carabidae, Lampyridae, Asilidae, Malachiidae, Sphecidae, and Nabidae. Of the pollinating insects, *Apis mellifera* L. was the species which was captured in greatest numbers; the average collected per trap each week was 1.69. Other species of the families Anthophoridae, Colletidae, Megachilidae, Andrenidae and other Apidae were captured less frequently.

Parasitoids were trapped in lesser numbers. Thiphiidae, Ichneumonidae, and Braconidae were all trapped in very small quantities (less than 0.0158 per trap).

Fewer insects were captured in Manantlán, Jalisco, and the trapping was limited to phytophagous, pollinating and predaceous insects. The collections in this zone were generally less than 0.25 insects per trap per fortnight. Of the phytophagous insects captured, *E. basalis* was the most abundant in Manantlán, as well as in Huamantla. Perhaps one of the reasons why insects were captured less frequently than in Huamantla, is that the traps were set out in autumn when populations *M. murinus* were more abundant than populations of the other insects, thus the total number of organisms decreased.

In general, the effect of the attractants on other insect groups was low indicating that the attractant mixture demonstrated a selectivity in the capture of scarabs, *Macrodactylus* in particular. The most captured insect, other than *Macrodactylus*, was *Apis mellifera;* however, they did not surpass 2 insects per trap per week.

ACKNOWLEDGMENTS

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PROTEIN FEEDING ATTENUATES ATTRACTION OF MEXICAN FRUIT FLIES (DIPTERA: TEPHRITIDAE) TO VOLATILE BACTERIAL METABOLITES

DAVID C. ROBACKER AND DANIEL S. MORENO
Crop Quality & Fruit Insects Research, Agricultural Research Service,
U. S. Department of Agriculture, 2301 S. International Blvd.
Weslaco, TX 78596

ABSTRACT

We tested the hypothesis that Mexican fruit flies [*Anastrepha ludens* (Loew)] are attracted to odor of tryptic soy broth cultures of *Staphylococcus aureus* (Rosenbach) because they are hungry for protein. First, we demonstrated that attraction to the odor was attenuated by feeding on a relatively complete diet containing sugar, protein, fats, vitamins, and minerals compared to feeding on sugar only; second, we showed that feeding on a diet of casein hydrolysate and sugar in which the percentage of protein was equal to that in the complete diet attenuated attraction to the same degree as the complete diet; and third, we showed that attraction to bacterial odor decreased as percentage of protein increased in a diet containing casein hydrolysate and sugar. Results of the three experiments support the hypothesis that flies are attracted to odor of *S. aureus* cultures largely to find protein. Dietary vitamins, minerals, fats, and percentage of protein as amino acids had no effect.

Key Words: *Anastrepha ludens*, kairomones, bacteria, specific-hunger

RESUMEN

Se puso a prueba la hipótesis de que la mosca Mexicana de la fruta [*Anastrepha ludens* (Loew)] es atraída por el olor de cultivos en caldo de soya de la bacteria *Staphylococcus aureus* por estar ávida de proteína. Primeramente, se comprobó que la atracción de las moscas hacia el olor fue mas tenue cuando estas se alimentaron de una dieta relativamente completa (azúcar, proteína, aceite, vitaminas y minerales) que cuando se alimentaron de una dieta que contenía solamente azúcar; en segundo lugar, se comprobó que alimentándose de una dieta que contenía caseína hidrolizada y azúcar (cantidad de proteína equivalente a la dieta relativamente completa) la respuesta de las moscas fue tenue y del mismo grado que cuando se alimentaron de la dieta relativamente completa; en tercer lugar, se comprobó que la atracción de las moscas hacia el olor de la bacteria disminuyó con el incremento de caseína hidrolizada en la dieta. Los resultados de los tres experimentos apoyan la hipótesis de que las moscas son atraídas por el olor de los cultivos de *S. aureus* porque estas buscan proteína para alimentarse. Los compuestos nutritivos de vitaminas, minerales, aceites, y porcentaje de proteína, en forma de amino ácidos, no afectaron las respuestas.

Odors produced by numerous species of bacteria have now been shown to be attractive to adults of various species of Tephritidae (Drew et al. 1983, Courtice & Drew 1984, Drew & Lloyd 1989, Jang & Nishijima 1990, MacCollom et al. 1992). The Mexican fruit fly [*Anastrepha ludens* (Loew)] is strongly attracted to odors produced during fermentation of culturing media by bacteria from at least four families (Robacker et al. 1991, Martinez et al. 1994). Robacker et al. (1993) later presented evidence that the attractive chemicals, hereafter referred to as bacterial odor, are probably volatile metabolites of the bacterial fermentation process.

The reason for the attractiveness of bacterial odor has been studied in recent work with the Mexican fruit fly but remains unresolved. Robacker (1991) showed that flies fed yeast hydrolysate and sugar were much less responsive to odor of cultures of the bacterium *Staphylococcus aureus* (Rosenbach) than flies fed only sugar and concluded that bacterial odor attracted flies hungry for protein, which is present in yeast hydrolysate. However, Robacker & Garcia (1993) later found that flies fed yeast hydrolysate up until the time of bioassays nevertheless were strongly attracted to bacterial odor. They also showed that sugar deprivation greatly depressed attraction of flies to the odor. This raised the question of whether decreased attraction to bacterial odor in tests where flies had been fed yeast hydrolysate may have been at least partly due to insufficient sugar in the yeast hydrolysate/sugar diets. The role of protein hunger in attraction to bacterial odor was again open for debate. During scrutiny of earlier data, another point of uncertainty came up regarding the composition of yeast hydrolysate itself. As yeast hydrolysate contains fats, vitamins and minerals in addition to protein, we now had to ask if the effects of feeding flies yeast hydrolysate on reducing attraction to bacterial odor may have been due to some nutrient or nutrients other than protein. This seemed like a strong possibility in light of recent work showing that two species of predatory mites fed a diet deficient in carotenoid vitamins were attracted to kairomones produced by prey that contain the carotenoids, while the same two mite species fed diets containing carotenoids did not respond to those kairomones (Dicke et al. 1986, Dicke 1988).

The purpose of this work was to determine how feeding by adult Mexican fruit flies on diets containing various nutrients affected attraction of the flies to bacterial odor produced by action of *S. aureus* strain RGM-1 (Robacker et al. 1991) on tryptic soy broth media. This was done in three experiments. First, a comparison was made of attraction of flies fed a diet containing a relatively complete mixture of nutrients vs only sugar to verify that some nutrient or nutrients in the complete diet would in fact attenuate responses of the flies to the bacterial odor. Next, a comparison was made of attraction of flies fed the complete diet vs a diet containing an equal amount of protein, but no other nutrients (except sucrose), to determine the role of nutrients other than protein. Finally, we tested for effects of diets containing various percentages of protein and sugar and no other nutrients.

Materials and Methods

Flies were from a colony maintained for approximately 400 generations with no wild-fly introductions. Mixed-sex groups of 180-200 flies were held in bioassay cages from eclosion with water and various test diets that will be described below. To ensure that flies would not respond strongly to water in both the treatments and the controls, water was provided to them in a light spray during the morning at least one h before bioassays began. Laboratory conditions, both for holding flies and conducting experiments, were 22 ± 2°C (range), 55 ± 15% RH (range) and a photoperiod of 13:11 (L:D). Laboratory lighting was a combination of fluorescent and natural light through glass windows.

The bacterial attractant was produced by fermentation of the bacterial strain RGM-1 previously identified as a probable new strain of *S. aureus* from the mouthparts of a female laboratory-strain Mexican fruit fly (Robacker et al. 1991). While this bacterium probably was introduced into the fruit fly culture from human contact, its cultures are nevertheless very attractive to adult Mexican fruit flies.

RGM-1 was cultured in tryptic soy broth (DIFCO Laboratories, Detroit, MI) in a shaker for 144 h at 30°C. Bacterial culture was centrifuged at 10,000 rpm for 20 min.

The resulting supernatant contained highly attractive material that was used as the attractant source in this research. Previous research had demonstrated that the attractive material in the supernatant was neither bacterial cells nor the tryptic soy broth itself (Robacker et al. 1993). Rather, the attractiveness probably was due to odorant chemicals produced by the bacteria during metabolism of nutrients in the tryptic soy broth.

Bioassays were conducted in 0.3 × 0.3 × 0.3 m, aluminum-framed, aluminum-screened cages. Cage-top bioassays (Robacker et al. 1991) were used in all experiments because this system has provided rapid, quantitative evaluation of attractants ranging from slightly to very attractive. Briefly, the bioassay consisted of placing two filter paper triangles (three cm per side) containing 10 μl of supernatant of bacterial culture and two papers containing 10 μl of water, each on one corner on the top of a bioassay cage, and counting the flies beneath the papers 10 times at one minute intervals. Filter papers were raised 0.5 cm above the cage top to ensure that olfaction was solely responsible for attraction of the flies to the filter papers. Bioassays were conducted using 7- to 11-day-old flies. Flies were used for one bioassay, then discarded.

Three experiments were conducted. The purpose of Experiment 1 was to test the hypothesis that flies fed a diet presumed to be more or less nutritionally complete would be less responsive to bacterial odor than flies fed sugar only, as was suggested by results of earlier research (Robacker 1991, Robacker & Garcia 1993). In Experiment 1, two diet types were tested. Ten cages of flies were set up with sugar and water only. Sugar was provided as four sucrose "dainty cubes"® (Imperial Sugar Co., Sugarland, TX) placed in petri dishes inside the cages. Water was provided in a plastic vial with a cotton wick inside cages. A second ten cages were prepared with water and a relatively "complete" diet. Water was provided in plastic vials as above and the complete diet was provided in a plastic petri dish. The complete diet was a dry powder mixture containing 20% enzymatic yeast hydrolysate, 20% torula dried yeast, 4% casein, 2% Vanderzant's vitamin fortification mixture for insects, 0.05% cholesterol, 52.35% sucrose (all obtained from U.S. Biochemical Corp., Cleveland, OH), and 1.6% Beck's salts (BIO-SERV, Inc., Frenchtown, NJ). Both enzymatic yeast hydrolysate and torula dried yeast contained about 50% protein while casein was about 97% protein, according to the manufacturers. Thus the total protein in the complete diet was about 24%. Free amino acids were less than 10% of the diet. The other 50% of yeast hydrolysate and torula dried yeast consisted of unspecified carbohydrates, ash, water, and fiber according to information provided by U.S. Biochemical Corp., and probably small percentages of fats, minerals, and vitamins (Long 1961). Finally, additional sucrose was provided as two sugar cubes (Imperial Sugar Co.) located in the petri dish with the complete diet. The reason for additional sugar was to allow flies to "self-select" the amounts of sugar and protein in their diet (Waldbauer & Friedman 1991). Flies were fed these diets from eclosion and diets were not removed from cages when bioassays were conducted. Experimental procedure was to test two cages, one each of the two diet types, side by side (one m apart) at the same time. Five cages of each diet type were set up and tested as one set. The experiment was repeated with a second set of five cages of each diet set up and tested two weeks later.

Experiment 2 was conducted to determine if nutrients other than protein affect attraction of the flies to bacterial odor. Cages of flies were again set up with one of two diet types. Twenty cages were prepared with the complete diet, two additional sugar cubes and water vials as in Experiment 1. Another 20 cages were prepared with a casein hydrolysate and sugar diet, two additional sugar cubes and water vials. The casein hydrolysate diet was a dry powder mixture containing 27.4% vitamin- and salt-free casein hydrolysate (ICN Biomedicals, Inc., Irvine, CA) and 72.6% sucrose (U.S. Biochemical Corp.). The casein hydrolysate was about 87.5% protein with little or no other nutrients, according to information provided by ICN Biomedicals. The total protein in the diet was 24%, the same as in the complete diet. Free amino acids were about 18.5% of the diet. Experimental procedure was the same as in Experiment 1. Again, five cages of each diet type were set up and tested as one set. Four sets were tested at two week intervals. Also, two cages fed only four sugar cubes as in Experiment 1 were prepared and tested with each set to verify that low attraction of flies fed the two test diets was not due to fly batch.

Experiment 3 was conducted to determine the relationship between percentage of protein in the diet and attraction of the flies to bacterial odor. Each replication of the experiment consisted of eight cages set up with dry powder diets containing 0, 1, 2, 4, 8, 16, 32, or 64% protein. Casein hydrolysate (ICN Biomedicals, Inc.) was the protein source. Sucrose (U.S. Biochemical Corp.) made up the remainder of the diets. No additional sugar cubes were provided. Water was again provided in plastic vials. Experimental procedure was to set up the eight cages as described above using flies from the same batch and to test them within two h on the same day. The experiment was repeated eight times, each about two weeks apart.

Experiments 1 & 2 were analyzed by paired *t* tests of cages paired by test time (Snedecor & Cochran 1967). Data used in these *t* tests were differences between total counts at bacterial odor and water from each bioassay. Experiment 3 was subjected to 2-way analysis of variance of differences between counts at bacterial odor and water, separating out effects of test day and percentage of protein (Snedecor &Cochran 1967). Effect of percentage of protein was partitioned into linear regression of attraction on percentage of protein on the $\log_2$ scale. Paired *t* tests were also used to compare counts at bacterial odor to counts at water in some cases. Although count differences were used for statistical analyses, means and standard errors (SE) shown in figures were calculated using response ratios from individual bioassays because these were more appropriate for presentation. The response ratio from an individual bioassay was defined as the ratio of the total count at bacterial odor in that bioassay to the mean of total counts at all water-controls in the experiment that included that bioassay.

Results and Discussion

The results of Experiment 1 are shown in Fig. 1. Flies fed the complete diet were much less responsive to bacterial odor than were flies fed sugar only ($t = 10.4$, df = 9, $P < 0.001$). We interpret this to mean that flies fed only sugar were strongly attracted to bacterial odor because they associate bacterial odor with the presence of certain required nutrients that were deficient in the sugar diet. Conversely, flies that fed on the complete diet were not as strongly attracted to bacterial odor because the complete diet partially satisfied their hunger for whatever nutrients they associate with bacterial odor.

Despite lower attraction of flies fed the complete diet compared to flies fed sugar only (Fig. 1), bacterial odor was significantly more attractive than water controls for flies fed the complete diet ($t = 8.5$, df = 9, $P < 0.001$). Three possible explanations for this result are: 1) not all of the flies' nutritional needs were met by the complete diet compared to what they associate with bacterial odor; 2) the complete diet has everything they need but the attraction response to bacterial odor does not turn off completely unless hunger of flies is completely satiated, a state that may occur only when their crops are completely full; and/or 3) the bacterial odor contains one or more attractive chemicals that are not associated with the hunger response.

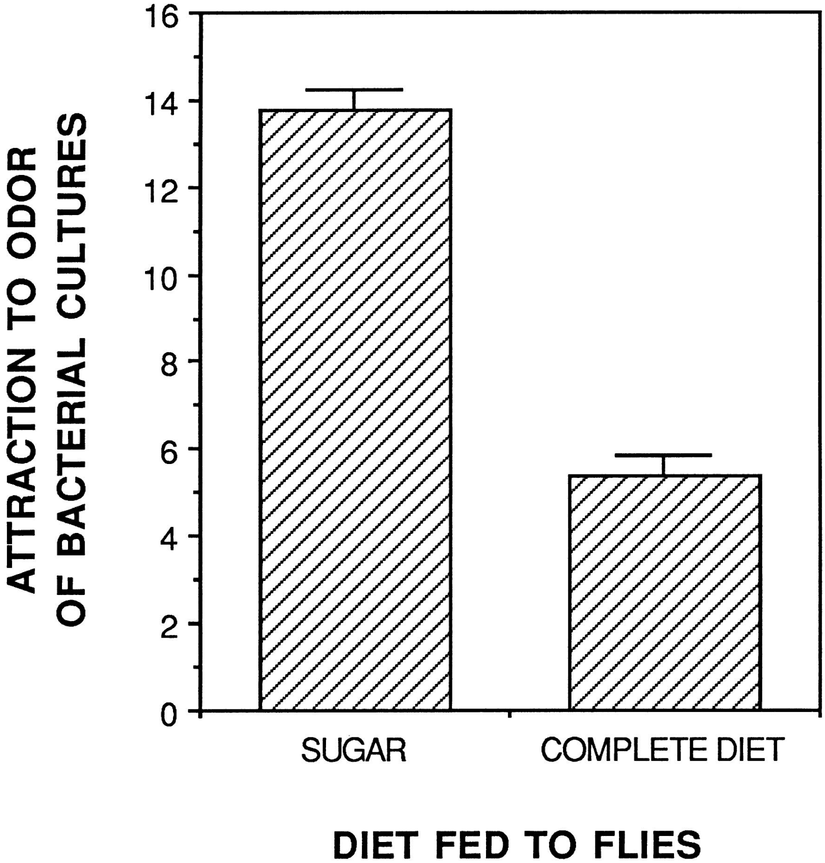

Fig. 1. Attraction to bacterial odor (± SE) of Mexican fruit flies fed sugar or a complete diet containing a balance of required nutrients. Bars are response ratios of attraction to bacterial odor relative to attraction to water controls. Attraction of flies fed the two diets was significantly different by a paired *t* test ($P < 0.001$, df = 9).

There was no difference in attraction of flies fed the complete diet or the casein hydrolysate/sugar diet ($t = 1.4$, df = 19, $P = 0.2$) (Fig. 2). Note that the two diets were equal in percentage of protein but differed in every other nutrient. For example, the casein hydrolysate diet contained almost no nutrients other than protein and sugar while the complete diet contained protein, sugar, vitamins, minerals, fats, etc. Further, the casein hydrolysate diet contained nearly twice as much of its protein as amino acids as did the complete diet. Indications are that the equal percentage of protein in the two diets was the primary factor determining equal attraction to the bacterial odor. This suggests that flies are attracted to bacterial odor largely because they associate it with the presence of protein.

As in Experiment 1, attraction to bacterial odor of flies fed diets containing protein in Experiment 2 was considerably lower than attraction of flies that were fed sugar only (Fig. 2). Also as in Experiment 1, attraction to bacterial odor nevertheless was

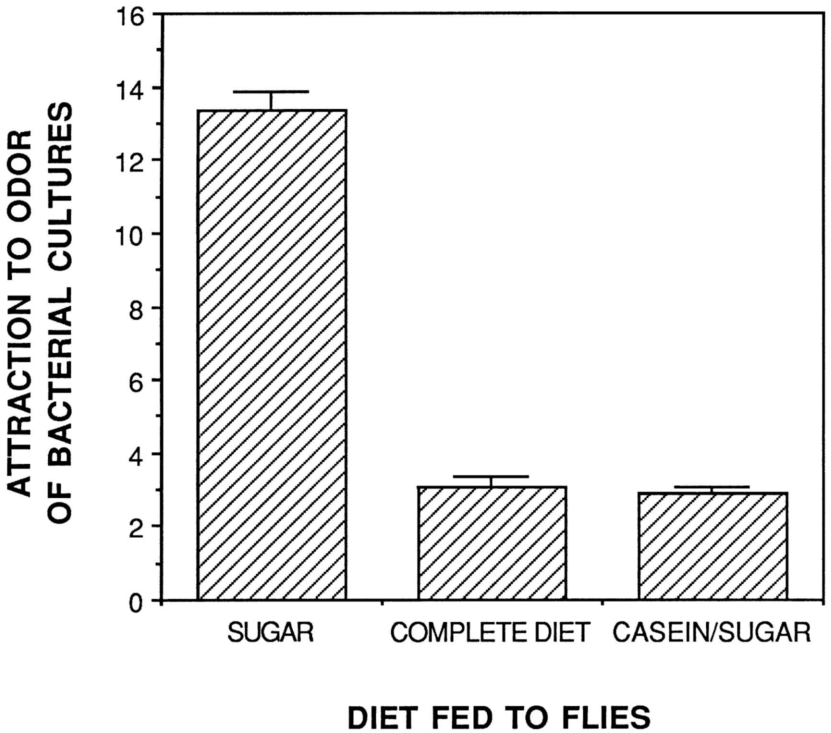

Fig. 2. Attraction to bacterial odor (± SE) of Mexican fruit flies fed sugar, a complete diet containing a balance of required nutrients, or a diet containing casein hydrolysate and sugar in which the percentage of protein was the same as that of the complete diet. Bars are response ratios of attraction to bacterial odor relative to attraction to water controls. Attraction of flies fed the complete diet and the casein hydrolysate diet was not significantly different by a paired t test ($P = 0.2$, df = 19).

significantly greater than attraction to water controls for flies fed the two protein-containing diets (complete diet: $t = 8.6$, df = 19, $P < 0.001$; casein hydrolysate/sugar diet: $t = 8.5$, df = 19, $P < 0.001$).

In Experiment 3, attraction of flies to bacterial odor was affected by diet fed to the flies (F = 44.2; df = 6,42; $p < 0.001$). Attraction decreased nearly linearly with the $\log_2$ of the percentage of protein ($r^2 = 0.55$, $P < 0.001$) (Fig. 3). Data for 64% protein were not included in Fig. 3 or in the analysis of variance because over 60% of the flies in the cages were dead by the test day, and most of the remaining flies appeared weak. The actual response ratio for the 64% protein diet was 0.6 indicating that fewer flies came to the bacterial odor than to water.

The results of Experiment 3 can be interpreted two ways. One explanation is that attraction of flies to bacterial odor decreased as percentage of protein in the diet increased because protein hunger decreased. This explanation corroborates our conclusion from Experiment 2 that flies are attracted to bacterial odor because they associate it with the presence of protein. However, the percentage of sugar in the diets decreased as the percentage of protein increased so the possibility that diminishing response by the flies may be due to increasing sugar hunger must be considered. This

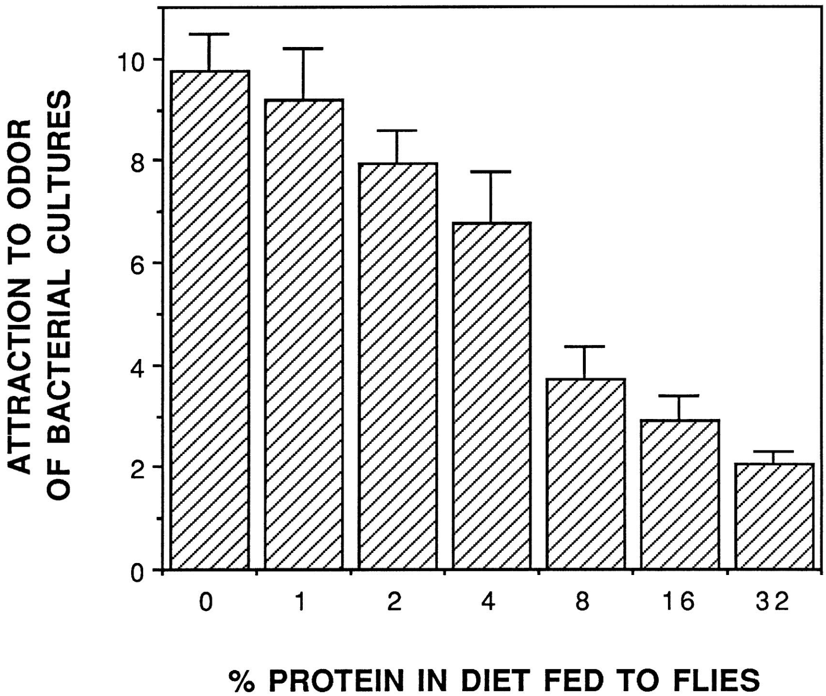

Fig. 3. Attraction to bacterial odor (± SE) of Mexican fruit flies fed diets containing sugar and various percentages of casein hydrolysate protein. Bars are response ratios of attraction to bacterial odor relative to attraction to water controls. Attraction of flies decreased nearly linearly with the $\log_2$ of percentage of protein ($r^2 = 0.55$, $P < 0.001$).

explanation is plausible because Robacker & Garcia (1993) showed that sugar-hunger greatly depresses attraction of Mexican fruit flies to bacterial odor.

We believe the explanation for the results of Experiment 3 is that the decrease in attraction was due to a decrease in protein hunger rather than an increase in sugar-hunger. There are several reasons for this contention. First, the diets depicted in Fig. 3 all contained at least 68% sugar. This percentage is well above the percentage of sugar (52.35%) in the complete diet that was found to optimize Mexican fruit fly fecundity and longevity (D.S.M. unpublished data). Second, most of the effect was manifest before the percentage of sugar in diets had dropped below 92%, a decrease in relative percentage of sugar of only 8% from the 100% sugar diet. At the same time, protein percentage increased from 0 to 8%, a large increase in relative percentage of protein. Thus, the change in sugar percentage probably was insignificant compared to the change in protein. Finally, the results of Experiment 2 in which attraction to bacterial odor were unaffected by a decrease in sugar percentage from 72.6% in the casein hydrolysate/sugar diet to 52.35% in the complete diet suggest that sugar percentage is unimportant as long as it is higher than some undetermined threshold level.

We conclude that attraction of Mexican fruit flies to odor of tryptic soy broth cultures of *S. aureus* strain RGM-1 is primarily due to hunger for protein. Presence or absence of fats, vitamins, and minerals seems unimportant. We suggest this is a "specific hunger" (Dethier 1976) for protein that translates into appetitive search for protein food sources due to an innate neural association of bacterial odor with the presence of protein. Possibly, attraction of fruit flies to bacteria generally may be governed by protein-hunger, based on the work of Drew & Lloyd (1989) that implicated bacteria as a natural protein source for fruit flies.

Endnote

We thank Jose Garcia and Maura Rodriguez for technical assistance and Sammy Ingle for insects. Mention of a proprietary product does not constitute an endorsement or recommendation for its use by the USDA.

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HOST SPECIFICITY OF SEVERAL *PSEUDACTEON* (DIPTERA: PHORIDAE) PARASITES OF FIRE ANTS (HYMENOPTERA: FORMICIDAE) IN SOUTH AMERICA

SANFORD D. PORTER,[1] HAROLD G. FOWLER,[2] SOFIA CAMPIOLO,[2]
AND MARCOS A. PESQUERO[3]

[1]Medical and Veterinary Entomology Research Laboratory, USDA, Agricultural Research Service, P.O. Box 14565, Gainesville, FL 32604

[2]Departamento de Ecologia, Instituto de Biociencias, Universidade Estadual Paulista, 13500, Rio Claro, SP, Brazil

[3]Departamento de Zoologia, Instituto de Biociencias, Universidade Estadual Paulista, 18610, Botucatu, SP, Brazil

ABSTRACT

We tested the host specificity of several parasitic *Pseudacteon* scuttle flies in South America with 23 species of ants in 13 genera. None of these ant species attracted *Pseudacteon* parasites except *Solenopsis saevissima* (F. Smith) and to a lesser extent *Solenopsis geminata* (Fab.). This result is encouraging because it indicates that the *Pseudacteon* flies tested in this study would not pose an ecological danger to other ant genera if these flies were introduced into the United States as classical biological control agents of imported fire ants. This prediction of host specificity will, of course, need to be validated with potential hosts in the United States before these flies can be released.

Key Words: Biocontrol, *Solenopsis*, Brazil

RESUMEN

Probamos la especificidad de hospedero de varias moscas parásitas del género *Pseudacteon* contra 23 especies de hormigas pertenecientes a 13 géneros en América del Sur. Ninguna de las hormigas atrajo moscas parásitas, con la excepción de *Solenopsis saevissima* (F. Smith) y, en menor escala, *Solenopsis geminata* (F.). Este resultado es alentador porque indica que las moscas *Pseudacteon* probadas en este ensayo no harían daños ecológicos a otros géneros de hormigas, si estas fueran introducidas en los Estados Unidos como agentes de control biolíógico conta las hormigas de fuego. Tal predicción de la especificidad de hospedero, claro, necesitaría ser valorada con hospederos potenciales en los Estados Unidos, antes que las moscas fueran liberadas.

When fire ants were introduced into the United States, they left behind almost all of their natural enemies in South America (Jouvenaz 1983). Consequently, release from natural enemies is a likely explanation for the 5- to 10-fold increase in fire ant densities reported in North America (Porter et al. 1992). A number of organisms have been considered as possible biological control agents for exotic fire ant populations, including micro-organisms, nematodes, a parasitic wasp, parasitic phorid flies, and other ants (Buren 1983, Feener & Brown 1992, Heraty et al. 1993, Jouvenaz et al. 1988, Patterson & Briano 1993).

Phorid or scuttle flies of the genus *Pseudacteon* Coquillett were proposed as biological control agents because of their dramatic impacts on fire ant foraging rates and the stereotypical defensive reactions of fire ant workers to scuttle fly attacks (Feener & Brown 1992, Porter et al. 1995a). But no matter how effective phorid flies might be in fire ant biocontrol, they cannot be released into the United States until it can be demonstrated that they will not cause ecological problems for native non-target organisms.

Available collection data indicates that individual *Pseudacteon* species are almost always specific to one genus of ants (Borgmeier 1962, 1963, 1969; Borgmeier & Prado 1975; Disney 1991, 1994; Williams & Banks 1987). The European species *Pseudacteon formicarum* (Verrall) has been reported from *Lasius* and several other ant genera (Donisthorpe 1927), but tests by Wasmann (1918) indicate that it is specific to *Lasius*. One rare South American species (*Pseudacteon convexicauda* Borgmeier) has been collected over *Solenopsis* and *Paratrechina* nests (Borgmeier 1962), but no details are given and this has not been confirmed by other collectors or the presence of developing larvae. A report that *Pseudacteon borgmeieri* Schmitz attacks both *Solenopsis* and *Camponotus* ants (Disney 1994) is based on a mistranslation of Borgmeier (1922), who actually stated that he only found this fly over *Solenopsis* nests even though he also inspected other ant nests including two species of *Camponotus*.

Sixteen South American *Pseudacteon* species have only been reported from *Solenopsis* ants (Disney 1994), including 13 with lobed ovipositors and three with unlobed ovipositors. Three additional South American *Pseudacteon* species plus several from North America have been reported attacking other ant genera. All of the new-world species reported from genera other than *Solenopsis* have unlobed ovipositors. The 20 or more new-world species of *Pseudacteon* with bilobed or trilobed ovipositors are reported to attack only *Solenopsis* ants (Borgmeier 1962, 1963, 1969; Borgmeier & Prado 1975; Disney 1991).

Many of the *Pseudacteon* species that attack fire ants in South America are broadly distributed (Borgmeier 1963, Borgmeier & Prado 1975) across the ranges of several fire ant species (Trager 1991). *Pseudacteon litoralis* Borgmeier, *Pseudacteon tricuspis* Borgmeier, *Pseudacteon obtusus* Borgmeier, *Pseudacteon wasmanni* (Schmitz) and *Pseudacteon curvatus* Borgmeier have all been collected attacking both *Solenopsis invicta* Buren and *Solenopsis saevissima* (F. Smith) (Williams 1980, Porter et al. 1995b, unpublished data). However, the fact that four *Pseudacteon* species in the United States all attack *Solenopsis geminata* (Disney 1991, Feener 1987), but not sympatric populations of the imported fire ant, *S. invicta*, suggests that some flies may also be specific to particular fire ant species or species groups (Feener & Brown 1992).

The objective of this study was to determine if the *Pseudacteon* flies that attack *Solenopsis* fire ants in South America will also attack other genera of South American ants.

Materials and Methods

In order to test the species specificity of *Pseudacteon* flies, we collected 23 species of ants in 13 genera. These ants were separated from their nest material and placed into white plastic trays coated with fluon so they could not escape. We used either 30 by 40 cm trays that contained 10-cm petri dish nests or 13 by 30 cm trays that contained water tube nests (Banks et al. 1981). Only one type of nest and tray was used at each location. During tests, lids on the petri dish nests were removed or ants were shaken out of nest tubes to expose as many ants as possible to potential phorid attacks. The number of ants in a tray varied between several hundred and several thousand depending on their size and availability. During tests, trays were carried to a test site and placed in shaded locations several m apart. All scuttle flies that appeared over the trays were collected using a double-chambered Allen aspirator (BioQuip®, Gardena, CA). This style of aspirator was particularly effective in capturing attacking flies (>90%) because the long flexible collection tube was easily maneuvered over the trays as the flies darted back and forth. A second advantage was that the inner chamber is a small vial that can be easily shaded with a hand so that the flies move into the light while the vial is being exchanged. Use of this aspirator was a considerable improvement over the snap-cap vial technique used by previous researchers (Williams 1980).

Tests were conducted using two different protocols. In the first set of tests, ants were set out for 75 min at a single location on the Rio Claro campus of São Paulo State University (UNESP-Rio Claro). Each test included one tray of fire ants (*S. saevissima*) and four to eight trays containing other species of ants. This procedure was repeated 19 times over a 27-day period from 11 December 1992 to 7 January 1993. The second set of tests was conducted in February, 1994 at five sample sites around each of two cities (Rio Claro, SP and Viçosa, MG). Sample sites were 1-10 km apart. Two clusters of 4-5 trays were set out at each site for 30-45 min; each cluster contained one fire ant colony and 3-4 other species of ants. Voucher specimens of ants and flies have been deposited with the Museu de Zoologia, Universidade de São Paulo, Brazil.

Results and Discussion

The *Pseudacteon* flies in our tests were specific to the genus *Solenopsis*. In the first series of tests at the single site on the UNESP Rio Claro campus, we collected *Pseudacteon* phorids from the tray with *S. saevissima* on 74% (14/19) of the observation days. Altogether, we collected 50 *Pseudacteon* flies: 47 - *P. litoralis*, 2 - *P. tricuspis*, 1 - *P. wasmanni*. No *Pseudacteon* flies were observed flying over any of the other ants tested (number of trials is shown in parentheses): *Atta sexdens* (18), *Monomorium pharaonis* (16), *Camponotus rufipes* (14), *Paratrechina sp.* (7), *Odontomachus minutus* (6), *Myrmelachista autori* (6), *Ectatomma quadridens* (5), *Pachycondyla striata* (5), *Pheidole* sp. 2 (5), *Crematogaster sp.* (4), *Pheidole oxyopus* (4), *Camponotus abdominalis* (3), *Camponotus blandus* (2). We also collected 11 *Myrmosicarius grandicornis* Borgmeier phorid flies from trays with *Atta sexdens* on eight different occasions. Two unidentified phorids (not *Pseudacteon*) appeared to be attracted to a *Paratrechina* sp. colony on two occasions.

Results for the second set of tests at sites around Rio Claro and Viçosa were similar. We collected *Pseudacteon* phorids at 75% of the nests with *S. saevissima* (7/10 in Rio Claro and 8/10 in Viçosa). We collected 23 *Pseudacteon* phorids at the Rio Claro sites (3 - *P. curvatus*, 3 - *P. tricuspis*, 7- *P. pradei*, 8 - *P. wasmanni*, 1 - *P. litoralis*, 1 - *P. borgmeieri*) and 12 more at the Viçosa sites (2 - *P. pradei*, 10 - *P. wasmanni*). We also collected three phorids (1 - *P. pradei*, 2 - *P. wasmanni*) that were attracted to a nest tray with black *Solenopsis geminata* (Fab.) at two of the five Viçosa sites. The other 10 species of ants tested did not attract phorid flies (the number of tray periods is shown in parentheses; two species have 10 periods because two trays were used at each site): Rio Claro Area -*Odontomachus brunneus* (5), *Acromyrmex rugosus* (10), *Pheidole* sp.(5), *Camponotus angulatus* (10); Viçosa Area - *Odontomachus haematodus* (5), *Dorymyrmex sp.* (5), *Atta sexdens* (5), *Camponotus rufipes* (5), *Camponotus* sp. 3 (5), *Paratrechina longicornis* (5).

When we compared the number of fire ant trays attracting *Pseudacteon* flies to the number of non-fire ant trays attracting *Pseudacteon*, the results were very significant, regardless of whether we analyzed results from the two tests separately or combined

(χ^2 tests, $P < 0.0001$). When we summed the numbers of scuttle flies collected from the campus tests with the numbers collected at the two multiple-site tests, four *Pseudacteon* species (*P. litoralis, P. wasmanni, P. pradei,* and *P. tricuspis*) were significantly more likely to be caught with fire ants than with non-fire ants (χ^2 tests, $P < 0.001$, $P < 0.001$, $P < 0.002$, and $P < 0.05$, respectively). Two species (*P. curvatus* and *P. borgmeieri*) were not collected frequently enough to make a determination. The 88 flies we collected over fire ant colonies were sufficient to have detected non-fire ant attraction rates as small as 3.5% at $P < 0.05$ (i.e.; 0.965^{88}). Statistical sensitivity for individual ant species was, of course, dependent on the number of scuttle flies collected when a particular ant species was available for attack. Statistical sensitivity ranged from 5% for *Atta sexdens* to about 25% for ant species only tested five times around the Viçosa area. Nevertheless, even if *Pseudacteon* flies had been attracted to other ant genera at some low rate, this would not necessarily mean that they would oviposit in them or that these ants would be suitable hosts for larval development.

Both *S. saevissima* and *S. geminata* were collected in the Viçosa area. *Solenopsis saevissima* was sparsely distributed in urban and agricultural sites while *S. geminata* was only found at two urban sites. No scuttle flies were found attacking *S. geminata* at either of its collection sites, although several scuttle flies were collected while attacking a *S. saevissima* colony at one of these sites.

In order to further investigate *Pseudacteon* attacks on *S. geminata* colonies, we returned to one of the Viçosa sites where we had previously captured phorids attacking *S. saevissima* nests. Trays with *S. saevissima* and *S. geminata* were set out alternately. When the *S. saevissima* trays were present, we observed 3-5 phorids continuously flying around the trays and attacking workers. After the *S. saevissima* trays were removed and the *S. geminat*a trays were set out, we observed only 1-2 phorids in the trays and the number usually declined to 0-1 after a couple of minutes. Within a minute or two after returning the *S. saevissima* trays, the number of scuttle flies increased to 3-5 again. This pattern was observed through three cycles of replacing *S. saevissima* colonies with *S. geminata* colonies. Careful observations of scuttle flies in the *S. geminata* colonies indicated that they did attempt to oviposit on some of the workers, but attempts were not very frequent, and the workers did not respond with the stilting behavior normally seen after *S. saevissima* workers have been attacked (Porter et al. 1995a). Many of the *S. geminata* workers were observed in a standard defensive posture with the head raised and the gaster curled under the thorax (Feener & Brown 1992), but general colony immobility was not observed (Porter et al. 1995a). Further tests will be necessary to determine if eggs are actually laid in *S. geminata* workers and whether they can produce viable larvae. At the end of the test, we collected four *P. pradei*, two *P. wasmanni,* and six *Pseudacteon affinis* Borgmeier over the *S. saevissima* nests.

Information from this study together with previous collection records (Borgmeier 1962, 1963, 1969; Borgmeier & Prado 1975) strongly indicate that most *Pseudacteon* parasites of fire ants will meet a critical requirement of a good biological control agent; that is, host specificity. The phorid flies tested in this study appear to be specific to a single genus of ants (*Solenopsis*) and perhaps to a specific subcomplex within that genus. These results are encouraging and should justify further and more extensive tests with ants from North America. Tests will also need to be done with other groups of insects, but it is highly unlikely that *Pseudacteon* flies would pose a threat to any arthropod group other than ants, considering their oviposition behavior, their highly specialized ovipositors, their specialized adaptations for pupation in the head capsules of worker ants (Porter et al. 1995b), and the fact that virtually all phylogenetically related phorid genera are ant parasites (Brown 1993, Disney 1994).

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EVALUATION OF PEANUT BREEDING LINES FOR RESISTANCE TO SILVERLEAF WHITEFLY (HOMOPTERA: ALEYRODIDAE)

HEATHER J. MCAUSLANE, DAVID A. KNAUFT[1,2] AND FREDDIE A. JOHNSON
Department of Entomology & Nematology, P.O. Box 110630, University of Florida, Gainesville FL 32611-0630

[1]Agronomy Department, P.O. Box 110500, University of Florida, Gainesville FL 32611-0500

[2]Current address: Crop Science Department, North Carolina State University, P.O. Box 7620, Raleigh NC 27695-7620

ABSTRACT

Silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, n. sp., is a new and occasionally damaging pest of peanut, *Arachis hypogaea* L., in Florida and other southern states. In 1992 and 1993, elite germplasm from the peanut breeding program at the University of Florida and several commercial cultivars were evaluated for resistance to silverleaf whitefly. In 1992, 52 genotypes that were chosen based on their performance in previous trials were evaluated. Numbers of whitefly red-eyed nymphs on peanut genotypes differed significantly. However, only two genotypes supported fewer whiteflies (although not significantly) than the cultivar 'Southern Runner'. In 1993, we evaluated selections of crosses between Florida parent material (81206 and 567A) and a North Carolina parent (GP-NC343) with multi-insect resistance. All selections tested had higher numbers of whitefly eggs and red-eyed nymphs than either 'Florunner' or 'Southern Runner'. No resistance to silverleaf whitefly was found in the peanut germplasm tested.

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Key Words: Plant resistance, *Arachis hypogaea*, *Bemisia argentifolii*, pest management

RESUMEN

La mosco blanca, *Bemisia argentifolii* Bellows & Perring, n. sp., es una nueva plaga que ocasionalmente daña el maní, *Arachis hypogaea* L., en la Florida y otros estados del sur. En 1992 y 1993, la resistencia a la mosca blanca fue evaluada en germoplasma élite del programa de propagación de maní de la Universidad de la Florida y en varios cultivares comerciales. En 1992, fueron evaluados 52 genotipos escogidos sobre la base de su comportamiento en pruebas previas. El número de ninfas en estado de ojos rojos sobre los genotipos de maní difirió significativamente. Sin embargo, solamente dos genotipos sportaron menos moscas blancas que el cultivar "Southern Runner". En 1993, evaluamos selecciones de cruces entre material parental de Florida (81206 y 567A) y de Carolina del Norte (GP-NC343) con resistencia a múltiples insectos. Todas las selecciones probadas tuvieron mayor número de huevos de mosca blanca y ninfas en estado de ojos rojos que "Florunner" y "Southern Runner". No se encontró resistencia a la mosca blanca en el germoplasma de maní probado.

The silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring [previously known as B strain of the sweetpotato whitefly, *Bemisia tabaci* (Gennadius)], has become a key pest of many agronomic, ornamental and vegetable crops since its first appearance in 1986 in Florida greenhouses (Price et al. 1987). *B. argentifolii* differs from *B. tabaci*, present in Florida since at least 1897 (Quaintance 1900), in host range (Byrne & Miller 1990), virus transmission capabilities, biology (Bethke et al. 1991, Costa & Brown 1991), production of honeydew (Byrne & Miller 1990), and insecticide resistance (Prabhaker et al. 1985). This whitefly caused at least $500,000,000 in losses to the agricultural community in 1991 alone (Perring et al. 1993). The damage produced by the whitefly includes plant debilitation due to feeding by immature stages and adults, product contamination with honeydew and resulting sooty mold, transmission of plant-pathogenic viruses and induction of physiological disorders.

Peanut, *Arachis hypogaea* L., is one of the new host plants infested by the silverleaf whitefly. Whiteflies were observed feeding in large numbers on peanut in northern Florida in 1988 and 1989, and many growers resorted to weekly applications of broad spectrum insecticides in an attempt to reduce populations (F.A.J., unpublished data). Despite heavy use of insecticides, some growers attributed yield losses of 459.5 kg per ha (2,500 lb per acre) to this whitefly (Leidner 1991).

In 1991, we initiated a search for resistance to silverleaf whitefly among common cultivars and breeding lines from the University of Florida peanut breeding program. Field trials in Georgia indicated that 'Southern Runner' appeared to be more resistant than 'Florunner' (Lynch & Chamberlin 1993); however, we found no significant differences among these cultivars and another four cultivars commonly grown in Florida (McAuslane et al. 1994). We screened 150 breeding lines and cultivars in 1991, and chose 52 of those with low whitefly infestations for further evaluation in 1992. This paper presents the results of the 1992 evaluation, and a 1993 test of several breeding lines incorporating North Carolina germplasm containing multi-insect resistance. The North Carolinan germplasm (GP-NC343) was originally released for resistance to southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber (Campbell et al. 1971). Later field research revealed that crosses incorporating GP-NC343 were resistant to thrips, leafhoppers, and defoliators (Campbell et al. 1987).

Materials and Methods

Tests-1992. On 29 June, 52 peanut selections (42 elite breeding lines and 10 released cultivars) were planted in a 0.3-ha field on the campus of the University of Florida, Gainesville, Alachua County. Plots were single rows, 6.1 m in length, spaced by 90 cm, and were replicated four times in a randomized complete block design. *Bacillus thuringiensis* [Dipel 2X, Abbott Laboratories, North Chicago, IL, (1.12 kg formulation per ha)] was applied on 18 and 23 September, and 9 October for control of lepidopterous defoliators. Chlorothalonil [Bravo 720, ISK Biotech Corp., Mentor, OH, (1.18 kg AI per ha)] was applied on 13 and 25 August, 11 and 23 September, and 9 and 27 October for control of early leaf spot, *Cercospora arachidicola* Hori, and late leafspot, *Cercosporidium personatum* Berk & Curt Deighton.

Plots were sampled at 10-d intervals from 6 August until 4 November by selecting 10 leaflets per plot. Leaflets were chosen from the fourth fully expanded leaf (any one of the four leaflets in the tetrafoliolate) below the terminal leaf on lateral branches. Previous research indicated that the greatest densities of red-eyed nymphs occurred in this region of the plant canopy (McAuslane et al. 1993). Leaflets were transported to the laboratory in a cooler, then refrigerated until immature whiteflies could be counted (48 h maximum). Red-eyed nymphs were counted on the bottom surface of each leaflet under 12x magnification. We measured the areas of leaflets sampled on 26 October using a leaf area meter (LI-COR, Model 3000, Lincoln, NE). Counts were standardized based on leaflet surface area. All data were converted to numbers of red-eyed nymphs per 5 cm^2 (= approximate area of one leaflet).

Tests-1993. On 3 June, seven pedigreed breeding lines (three produced by crossing 81206 with GP-NC343 and four produced by crossing 567A with GP-NC343), the parent with multi-insect resistance (GP-NC343), and two commercial cultivars ('Florunner' and 'Southern Runner') were planted in the same field that was used in 1992. Plots were two rows wide (row spacing of 90 cm) and 6.1 m long, and were replicated four times in a randomized complete block design. *Bacillus thuringiensis* and chlorothalonil, at the same rates as in 1992, were applied on 16 and 26 July, 6 and 26 August, and 20 September.

Plots were sampled as in 1992 at 10-d intervals from 15 July until 4 October, except that whitefly eggs and red-eyed nymphs were counted on the top and bottom surfaces of 20 leaflets per plot. The areas of leaflets sampled on 4 August and 23 September were measured using a leaf area meter. All data were converted to number of whitefly stages per 5 cm^2. Leaflet areas recorded on 4 August were used to convert whitefly counts obtained on the first five sample dates, and areas recorded on 23 September were used to convert counts on the last four dates.

Data were analyzed using the GLM procedure (SAS Institute 1987). Prior to analysis, count data were square root (x+1)-transformed to correct for nonnormality of the data and proportion data were arcsin (x)-transformed to correct for nonhomogeneity of variance. Means were separated using least significant differences at a significance level of 5% (SAS Institute, 1987). Untransformed means are presented in all tables and figures.

Results and Discussion

Tests-1992. Numbers of red-eyed nymphs counted on the lower surfaces of leaflets differed significantly among genotypes ($F = 1.57$; df = 51, 153; $0.01 < P < 0.05$). When genotypes were analyzed by date, they differed significantly on four of ten dates (4, 15, and 25 September and 15 October; $F = 1.51$; df = 51, 153) (Fig. 1). When genotypes were ranked by season-long infestation, F1138 (0.031 ± 0.011 red-eyed nymphs per 5

cm^2 leaflet surface) and F1084 (0.044 ± 0.015) were least infested, and 87118 was most infested (0.220 ± 0.042). In an adjacent test [(McAuslane et al. 1994)], 'Southern Runner' was also infested with very low numbers of red-eyed nymphs (0.049 ± 0.009). This adjacent cultivar experiment was treated and sampled in the same manner as the genotype trial. Although whitefly numbers on 'Southern Runner' cannot be compared statistically to numbers of whiteflies on the genotypes in this study, the data indicate that, under these infestation levels, no University of Florida genotypes were more resistant than cultivars already commonly grown in Florida. Up to 80% of whiteflies on the genotypes were parasitized by the end of the season (data not shown). Parasitism may have contributed to the low whitefly infestations observed in this trial.

Tests-1993. Date was a significant source of variability in numbers of eggs (F = 12.54; df = 8, 240; P < 0.01) and red-eyed nymphs (F = 10.58; df = 8, 240; P < 0.01). There were no interactions between date and cultivar. Genotype significantly influenced number of eggs (F = 20.14; df = 9, 27; P < 0.01) and red-eyed nymphs (F = 3.44; df = 9, 27; P < 0.01). GP-NC343 and all breeding lines except F1384 supported more whitefly eggs than either 'Florunner' or 'Southern Runner' (Table 1). However, only F1436, F1435 and GP-NC343 supported significantly more red-eyed nymphs than the two cultivars (Table 1). Numbers of eggs on genotypes differed significantly on all dates except the first and the last, while red-eyed nymph counts differed significantly on only four dates (13 and 24 August, and 3 and 23 September) (Fig. 2). Crosses between 81206 and GP-NC343 were significantly more infested with eggs than were crosses between 567A and GP-NC343. Cultivar 81206 is late-maturing and produces new vegetation throughout the season while 567A, which is early-maturing and more determinant, slows vegetative growth at the end of the season. (The presence of suc-

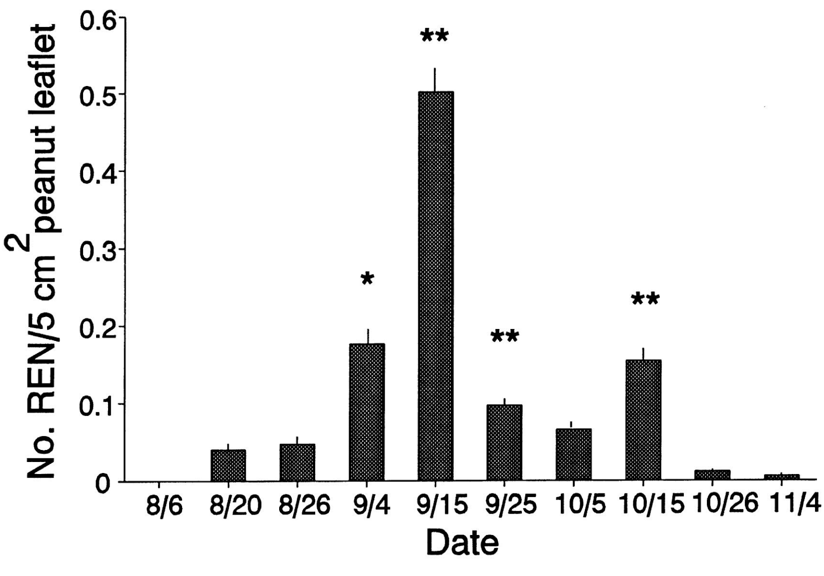

Fig. 1. Average number of red-eyed nymphs per peanut leaflet in Gainesville, FL, 1992. Counts were made on the lower surfaces of leaflets and data from all peanut selections were combined. Asterisks indicate dates on which counts differed significantly among genotypes (* = 0.01 < P < 0.05, ** = P < 0.01). Error bars are one standard error of the mean.

TABLE 1. AVERAGE NUMBER OF SILVERLEAF WHITEFLY EGGS AND RED-EYED NYMPHS (REN) PER PEANUT LEAFLET (STANDARDIZED 5 CM^2 AREA) IN GAINESVILLE, FL, 1993.

Accession Number	Parentage	Pedigree/Cultivar	Mean ± SEM[1]	
			Eggs	REN
F1437	81206xGP-NC343	8815B-4-2-2-3-B	2.67 ± 0.18a	0.16 ± 0.02bc
F1436	81206xGP-NC343	8815B-4-2-2-1-B	2.10 ± 0.12b	0.21 ± 0.02ab
F1435	81206xGP-NC343	8815B-3-2-1-1-b3	1.90 ± 0.10b	0.25 ± 0.03a
F1386	567AxGP-NC343	8816B-Bx4-TV-5-b3	1.54 ± 0.11c	0.12 ± 0.01cd
		GP-NC343	1.36 ± 0.08c	0.22 ± 0.02a
F1383	567AxGP-NC343	8816B-Bx4-RV-1-b2	1.36 ± 0.08c	0.13 ± 0.02cd
F1385	567AxGP-NC343	8816B-Bx4-TV-3-b3	1.26 ± 0.07cd	0.13 ± 0.02cd
F1384	567AxGP-NC343	8816B-Bx4-TV-1-b3	1.15 ± 0.08de	0.10 ± 0.02d
		'Florunner'	1.12 ± 0.07e	0.13 ± 0.02cd
		'Southern Runner'	1.07 ± 0.06e	0.14 ± 0.02cd

[1]Numbers within a column followed by the same letter did not differ significantly at $\alpha = 0.05$ (least significant difference test on square root [x + 1] transformed data).

culent new growth may have induced ovipositing whiteflies to lay eggs preferentially on the crosses incorporating 81206 germplasm.

In 1993, whitefly lifestages were counted on both surfaces of the peanut leaflet. McAuslane et al. (1993) found that up to 35% of whitefly red-eyed nymphs may occur on the top surface of peanut leaflets. Lynch & Simmons (1993) reported that the proportion of whitefly immature stages on top and bottom surfaces of 'Florunner' leaves changed over the course of sampling, with whiteflies becoming more common on the upper surface of leaflets at the end of the sample period. In this study, the distribution of eggs between top and bottom leaflet surfaces differed significantly among dates ($F = 23.55$; df = 8, 240; $P < 0.01$), and among cultivars ($F = 9.45$; df = 9, 27; $P < 0.01$), ranging from 76% of eggs on the bottom surface of F1435 leaflets to only 59% on the bottom surface of F1383. There was no date by cultivar interaction for either eggs or red-eyed nymphs. The distribution of red-eyed nymphs between top and bottom surfaces differed among dates ($F = 2.75$; df = 7, 133; $0.01 < P < 0.05$), but not among cultivars ($F = 1.62$; df = 9, 27; $P > 0.05$), averaging 61.3% on the bottom leaflet surface. Distribution of eggs and red-eyed nymphs between top and bottom leaflet surfaces followed a similar trend. Whiteflies were more common on the bottom surface of leaflets early in the season but were about equally abundant on top and bottom surfaces at the end of the sampling period. These results are similar to the findings of Lynch & Simmons (1993).

Three years of sampling silverleaf whitefly on peanut genotypes held by the University of Florida yielded no resistant germplasm. The germplasm evaluated represented an extensive cross-section of all four market types (runner, valencia, Spanish and virginia), and included a wide range of parent material. Many lines tested had multiple insect resistance (*e.g.*, NC-GP343), and multiple pest resistance (*e.g.*, 81206 lines have broad disease and nematode resistance). Under the infestation conditions experienced in 1992 and 1993, the cultivars commonly grown in Florida were more re-

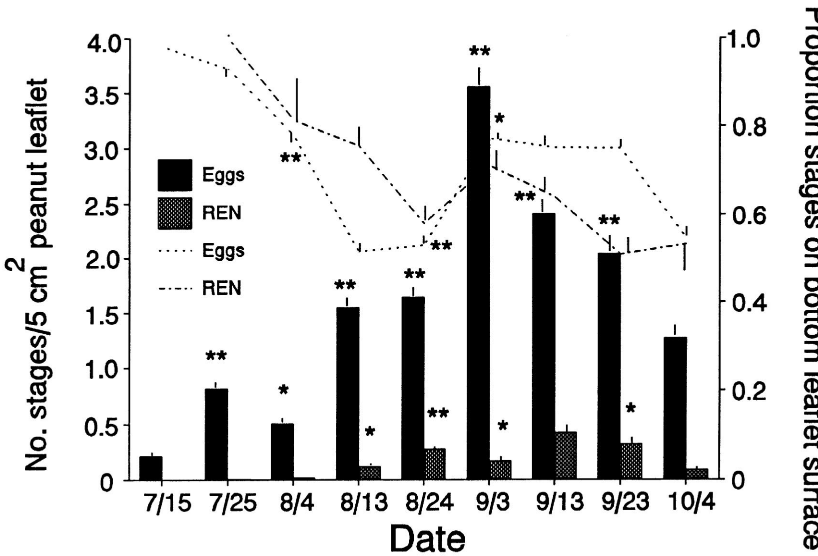

Fig. 2. Average number of eggs and red-eyed nymphs per peanut leaflet (bars) and proportion of each stage occurring on the bottom leaflet surface (lines) in Gainesville, FL, 1993. Whiteflies were counted on upper and lower surfaces of each leaflet, and data from all peanut selections were combined. Asterisks indicate dates on which counts differed significantly among genotypes (* = $0.01 < P < 0.05$; ** = $P < 0.01$). Error bars are one standard error of the mean.

sistant than were the genotypes tested. These data indicate that breeding for peanut resistance to silverleaf whitefly is likely to be difficult, and that alternative management strategies should be emphasized. Previous research (McAuslane et al. 1993, 1994) has indicated that native aphelinid parasitoids contribute heavily to whitefly mortality in peanut fields when *Bacillus thuringiensis* is the only insecticide used. Management of silverleaf whitefly in Florida peanuts may depend on cultural practices (such as early planting or trap cropping), and on conservation of populations of natural enemies by avoiding the use of broad spectrum insecticides.

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EFFICACY OF EMAMECTIN BENZOATE AND *BACILLUS THURINGIENSIS* AT CONTROLLING DIAMONDBACK MOTH (LEPIDOPTERA: PLUTELLIDAE) POPULATIONS ON CABBAGE IN FLORIDA

GARY L. LEIBEE[1], RICHARD K. JANSSON[2], GREGG NUESSLY[3] AND JAMES L. TAYLOR[4]

[1]University of Florida Central Florida Research and Education Center
Institute of Food and Agricultural Sciences 2700 East Celery Avenue
Sanford, FL 32771

[2]Merck Research Laboratories P. O. Box 450 Hillsborough Road
Three Bridges, NJ 08887

[3]University of Florida Everglades Research and Education Center
Institute of Food and Agricultural Sciences P. O. Box 8003
Belle Glade, FL 33430

[4]Merck Research Laboratories P. O. Box 1893
Sanford, FL 32772

ABSTRACT

Emamectin benzoate (MK-244; Merck & Co., Rahway, NJ), used alone and alternated with *Bacillus thuringiensis* (Berliner) ssp. *aizawai* (*Bta*), *Bta* alone, and *B. thuringiensis* ssp. *kurstaki* (*Btk*) alone, were evaluated for control of diamondback moth, *Plutella xylostella* (L.), in head cabbage at three locations in Florida. Additional treatments unique to each location were also evaluated. Emamectin benzoate alone, *Bta* alone, emamectin benzoate alternated with *Bta*, and mevinphos were shown to be effective. *Btk* was less efficacious than *Bta* at two locations.

Key Words: *Plutella xylostella*, emamectin benzoate, *Bacillus thuringiensis*, field efficacy

RESUMEN

El benzoato de emamectina (MK-244; Merck & Co., Rahway, NJ) usado solo y alternado con *Bacillus thuringiensis* (Berliner) ssp. *aizawai* (Bta), Bta solo, y *B. thuringiensis* ssp *kurstaki* (Btk) solo, fueron evaluados para el control de la polilla de diamante, *Plutella xylostella* (L.), en col de repollo en tres localidaes de la Florida. También fueron evaluados tratamientos adicionales únicos en cada localidad. El benzoato de emamectina solo, Bta solo, el benzoato de emamectina alternado con Bta, y el mevinfós mostraron ser efectivos. Btk fue menos eficaz que Bta en las dos localidades.

The diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), a worldwide pest of cruciferous crops (Talekar 1986), was easily managed in Florida until the onset of insecticide resistance in the 1980s (Leibee & Savage 1992a,b). Loss of efficacy with pyrethroids and methomyl caused growers to switch to intensive use of other insecticides, especially *Bacillus thuringiensis* (Berliner) ssp. *kurstaki* (*Btk*). Shelton et al. (1993) documented resistance to *Btk* and control failures with *Btk* products in several populations of diamondback moth in Florida in 1992. At present, the diamondback moth has become very difficult to control with any of the currently registered synthetic insecticides and *Btk*-based products. The recently introduced products based on *B. thuringiensis* (Berliner) ssp. *aizawai* (*Bta*) appear to be providing effective control of diamondback moth in Florida. This is consistent with reports describing resistance to *Btk*, but not to *Bta*, in Florida (Leibee & Savage 1992c, Shelton et al. 1993).

The development of new insecticides that circumvent the mechanisms of resistance that have developed in the diamondback moth has become extremely important, not only for control, but also for management of insecticide resistance. The availability of several new insecticides with different chemistry and mode of action would allow the implementation of management schemes designed to slow down the selection for resistance to any one insecticide. Emamectin benzoate (MK-244) is a new avermectin insecticide in development at Merck Research Laboratories targeted for control of lepidopterous pests on a variety of crops.

This study was conducted to compare the efficacy of emamectin benzoate used alone and alternated with *Bta*, *Bta* alone, and *Btk* alone for control of diamondback moth on cabbage at three locations in Florida. Additional treatments unique to each location were also evaluated.

MATERIALS AND METHODS

Studies were conducted in Florida during 1992 at the Central Florida Research and Education Center (CFREC) in Sanford, Everglades Research and Education Center (EREC) in Belle Glade, and the Tropical Research and Education Center (TREC) in Homestead. Additional studies were conducted during 1993 at the EREC.

Insecticidal Treatments

The insecticides common to all three locations were emamectin benzoate [MK-244 0.16 EC (emulsifiable concentrate), Merck Research Laboratories, Merck & Co., Rahway, NJ] at 0.0084 kg (AI)/ha, *B. thuringiensis* ssp. *aizawai* (*Bta*) (XenTari, Abbott Laboratories, North Chicago, IL) at 1.12 kg/ha, and *B. thuringiensis* ssp. *kurstaki* (*Btk*) (DiPel 2X, Abbott Laboratories, North Chicago, IL) at 1.12 kg/ha. Additional insecticides, adjuvants, and combinations tested at TREC were: *Btk* [AC 513,696 2X WP (wettable powder), American Cyanamid Co., Princeton, NJ] at 1.12 kg/ha; *Btk* [AC 513,696 48 LC (liquid concentrate), American Cyanamid Co.] at 2.8 liter/ha; *Btk* [Larvo-Bt LC (liquid concentrate), Knoll Bioproducts Co., Inc., Santa Fe, NM] at 0.3 liter/ha alone and at 0.3 liter/ha in combination with a feeding stimulant (Konsume, Fermone, Phoenix, AZ) at 7.0 liter/ha; AC 513,696 48 LC at 2.8 liter/ha in combination with Konsume at 7.0 liter/ha; *Btk* transconjugate [Cutlass WP (wettable powder), Ecogen, Inc., Langhorne, PA] at 2.24 kg/ha; and mevinphos [Phosdrin 4 EC (emulsifiable concentrate), E. I. duPont de Nemours & Co., Wilmington, DE] at 0.56 kg (AI)/ha in combination with Cutlass WP at 2.24 kg/ha. Additional insecticides and combinations tested at EREC were: *Btk*/*Bta* transconjugate [Condor OF (oil flowable), Ecogen, Inc., Langhorne, PA] at 2.34 liter/ha; *Btk* recombinant (MVP, Mycogen Corp., San Diego, CA) at 4.67 liter/ha; Cutlass WP at 2.24 kg/ha; *Btk* [Javelin WG (wettable powder), Sandoz Agro, Inc., Des Plaines, IL] at 1.12 kg/ha; *Btk* [Biobit FC (flowable concentrate), E. I. duPont de Nemours & Co., Wilmington, DE] at 3.5 liter/ha; thiodicarb [Larvin 3.2 AF (aqueous flowable)], Rhone-Poulenc Ag Co., Research Triangle Park, NC] at 0.9 kg (AI)/ha; methamidophos [Monitor 4 EC (emulsifiable concentrate), Miles, Inc., Kansas City, MO] at 1.12 kg (AI)/ha; Larvin 3.2 AF at 0.9 kg (AI)/ha in combination with DiPel 2X at 1.12 kg/ha; esfenvalerate [Asana XL 0.66 EC (emulsifiable concentrate), E. I. duPont de Nemours & Co., Wilmington, DE] at 0.055 kg (AI)/ha; Asana XL at 0.055 kg (AI)/ha in combination with DiPel 2X at 1.12 kg/ha; mevinphos (Phosdrin 4EC) at 1.12 kg (AI)/ha; and mevinphos at 1.12 kg (AI)/ha in combination with DiPel 2X at 1.12 kg/ha.

Two alternating application patterns were used for emamectin benzoate and *Bta* at CFREC. One pattern started with two applications of emamectin benzoate and then rotated every two applications with *Bta*; the other alternation started with *Bta* and rotated every two applications with emamectin benzoate. Also at CFREC, an additional *Bta* treatment was tested in which applications were skipped if the infestation level was ≤ 5%. At TREC, one alternation pattern starting with *Bta* was used as described above. At EREC, the pattern tested was three applications of emamectin benzoate followed by three applications of *Bta*.

CFREC-Sanford

'Golden Acre' cabbage was transplanted on 4 Mar. 1992 into Myakka fine sand. Plots consisted of four 9.0-m rows with a 0.76-m row spacing and about a 0.28-m plant spacing. Four rows were left unplanted between each plot to provide a separation of 3.8 m. Plots were arranged in five blocks and the blocks were separated by 7.6-m alleyways. All the treatments were assigned to plots in a randomized complete block design with five replications. Conventional cultural practices were used for fertilization and weed control.

Sprays were applied with a tractor-mounted, compressed-air sprayer. Three hollow-cone nozzles (D2-25) were used per row; one overhead and one drop on each side. The delivery rate of spray was 467.4 liter/ha with a boom pressure of about 3.2 kg/cm^2 (45 psi) and a speed of 3.2 km/h. Application dates were 26 March, 1, 8, 15, 22, and 29 April, and 6 and 13 May 1992. A buffer (Helena Buffer PS, Helena Chemical Co., Memphis, TN) was used to maintain the pH of the spray water at 6.9. A spreader-sticker (Triton B-1956, Rohm and Haas Co., Philadelphia, PA) was used in all treatments at the rate of 5.0 ml per 7.6 liter of spray. The nontreated check received water and spreader-sticker at each application.

Ten plants per plot (5 randomly selected plants in the center of each of the two middle rows) were examined weekly to determine the presence or absence of larvae and pupae of each species on the bud (or head if formed) and next 4 youngest leaves. At harvest (14 May), 10 mature plants (5 randomly selected plants in the center of each of the two middle rows) were each placed into one of six damage categories. The head and first four wrapper leaves were cut as a unit from the plant. Each wrapper leaf was removed and inspected and then the head was inspected. A scale of 1 to 6, similar to that of Greene et al. (1969), was used, in which 1 = no damage; 2 = no head damage with minor feeding damage on wrapper leaves, found only by close inspection; 3 = no head damage with obvious damage to wrapper leaves, generally obvious before removal of wrapper leaves; 4 = very minor feeding damage on head, not completely through outer head leaves, evident only by close inspection; 5 = feeding completely through outer head leaf or further into head; 6 = similar to 5 but more extensive, damage radiates further towards or past equator of head from top or bottom and laterally around head. A damage rating of ≤ 3 is marketable under normal market conditions, wrapper leaves might be removed to market. A damage rating of ≤ 4 is marketable under exceptional market conditions.

TREC-Homestead

'Rio Verde' cabbage seeds were incorporated into a germination mix (Pro-Mix) and direct-seeded into a Krome, very gravelly loam soil on 8 January 1992. The soil was fumigated with Terr-O-Gas (75% methyl bromide, 25% chloropicrin; 246 kg/ha) and covered with white on black plastic mulch on 27 December 1991. Plants were spaced 0.3-m apart within rows and 0.76-m apart between rows on 1.8 m-center beds. Conventional cultural practices were used for fertilization and weed control. All treatments except the emamectin benzoate (MK-244)/XenTari rotation treatment were applied on 7 dates between 14 February and 27 March. Plants receiving the emamectin benzoate/XenTari rotation treatment were sprayed with XenTari on 4 dates (14 and 21 February, and 13 and 20 March) and with emamectin benzoate on the three remaining dates (28 February, and 6 and 27 March). Treatments were replicated 4 times in a randomized complete block design. Treatment plots were 4 rows (2 beds) by 9.1-m long. A 1.5-m long section of nontreated plants separated replicates. Applications were made using a tractor-mounted, single bed boom sprayer that operated at 6.9 kg/cm^2 (100 psi) and delivered 935 liters/ha through 6 D-4 Albuz red disc type ceramic cone nozzles at 4.8 km/h. All treatments were applied in water. The pH of the water was maintained between 6.5 and 7.5 using sulfuric acid buffer. All treatments were applied with a surfactant, Triton B-1956, (0.49 liters/ha). The nontreated check was not sprayed. Eight plants per plot (4 randomly selected plants in the center of each of the two middle rows) were examined on 6 dates between 4 February and 19 March to determine numbers of larvae and pupae per plant. Foliage injury was rated on 24 plants per plot (12 randomly selected plants in the center of each of the two middle rows) at harvest (6 April), using a scale of 1-6 as previously described. Percentages of marketable heads were based on ratings ≤ 3.

EREC-Belle Glade

Both the 1992 and 1993 trials were conducted on Lauderhill soil. The following methods and materials were common to both trials. 'Bravo' cabbage was direct-seeded to raised beds on 0.91-m centers. Seeds were planted to two rows spaced 0.3-m apart on each bed and later thinned to 0.3-m spacing between plants within each row. Treatments were replicated four times in a randomized complete block design. The nontreated check plots received no treatments. The pH of the spray water ranged from 6.4 to 6.6 and was not adjusted. A CO_2 pressurized hand sprayer boom was used to spray two beds simultaneously. Except for the Condor OF treatment in 1992, wetting agents were used. Leaf Act 80 [PureGro Co., West Sacramento, CA (0.58 liter/ha)] was used with the emamectin benzoate treatments, and X-77 [Chevron Chemical Co., San Francisco, CA (0.29 liter/ha)] was used for the rest of the treatments. Conventional cultural practices were used for fertilization and weed control. Ten plants per plot (5 randomly selected plants in the center of each of the two middle rows) were examined on each sampling date to determine numbers of larvae and pupae. Marketability was determined at harvest for heads with wrapper leaves and for heads with no more than three wrapper leaves removed. Percentages of marketable heads were based on ratings ≤ 2 (Greene et al. 1969).

In 1992, seeds were planted on 24 January. Treatment plots were two beds wide (4 rows) and 7.62-m long with a 1.52-m nonplanted buffer zone between plots. Applications were initiated when diamondback moth populations averaged < 1 larva per plant. Treatments were applied eight times: 5, 17, and 27 March, 9, 16, and 30 April, and 7 and 22 May. The spray boom had three nozzles over each bed: one centered over each bed and one on each side of the row directed inward. Volume of water applied was 374 liter/ha for the first two sprays. Water volume was increased to 607 liter/ha beginning 25 March, and increased again to 748 liter/ha from 16 April until the last spray on 22 May. Plots were sampled on 3, 10, 20, and 25 March, 1, 13, and 20 April, and 5 and 19 May. Plants were harvested on 28 May.

In 1993, Diazinon 14G was applied and incorporated into the soil 15 days before planting for wireworm control. Seeds were planted on 16 March. Applications began when diamondback moth populations averaged slightly more than 1 larva per plant. Treatment plots were four beds wide (8 rows) and 6.1-m long with a 1.52-m nonplanted buffer zone between plots. Treatments were applied 7 times: 23 and 30 April, 6, 13, and 24 May, and 2 and 6 June. The spray boom had four nozzles over each bed: one over each row and one on each side of the bed directed inward. Volume of water applied was 374 liter/ha for the first two sprays. Water volume was increased to 607 liter/ha beginning 6 May, and increased again to 748 liter/ha from 24 May until the last spray. Plots were sampled on 21 and 29 April, 5, 11, 20, and 26 May, and 8 and 16 June. Plants were harvested on 18 June. The majority of the insect pressure in both trials was from diamondback moth. Very few southern armyworm, *Spodoptera eridania* (Cramer); beet armyworm, *S. exigua* (Hübner); cabbage looper, *Trichoplusia ni* (Hübner); and cutworms, probably *Agrotis ipsilon* (Hufnagel)and *Feltia subterranea* (F.), were encountered during the experiment.

Statistical analysis

Data were subjected to analysis of variance [SAS System, Version 6.04 (SAS Institute, Inc., Cary, NC)]. Insect count data from Belle Glade and Homestead were 1n (x + 1)- transformed. All percentage data were transformed [ARCSIN (SQRT X)]. Means were separated by Waller-Duncan K-ratio t-test, (K-ratio = 100).

RESULTS AND DISCUSSION

Sanford

Due to consistently low numbers of diamondback moth and the lack of correlation between larval counts and marketability in past studies at CFREC-Sanford, the percentage of plants with the bud (or head) and next 4 youngest leaves infested was used to measure the activity of diamondback moth. This method was found to work well when abundance was low and results correlated well with levels of damage at harvest (G.L.L., unpublished data). We suggest that this method works because efficacious insecticides prevent development to the adult stage, thus preventing oviposition on the new growth in the sampling zone which eventually becomes the marketable portion of the plant. In addition, we suggest that this method also works because there is very little immigration from adjacent plots which may be producing adults.

Infestation levels increased steadily from 16% on 24 March to 98% on 12 May in the nontreated check (Table 1). Weekly applications of emamectin benzoate resulted in very low infestation levels (Table 1) and the highest percentage of marketable cabbage (Table 2). Starting with emamectin benzoate and alternating every two applications with two applications of XenTari also resulted in very low infestation levels (Table 1) and a comparable percentage of marketable cabbage (Table 2). Starting with XenTari and alternating every two applications with two applications of emamectin benzoate resulted in significantly higher infestation levels and significantly ($P < 0.05$) less marketable cabbage than the opposite alternation pattern. This difference in ef-

TABLE 1. EFFECTS OF INSECTICIDES ON MEAN PERCENTAGE OF CABBAGE PLANTS INFESTED WITH LARVAE AND/OR PUPAE OF THE DIAMONDBACK MOTH AT CFREC-SANFORD, FL, 1992.

		Sample Date							
		24 Mar	31 Mar	7 Apr	14 Apr	22 Apr	28 Apr	5 May	12 May
Treatment	Rate per Hectare[1]	% Plants Infested with Diamondback Moth Larvae and/or Pupae (SEM)[2]							
Nontreated	—	16(5.6) NS	20(7.1) a	41(8.0) a	34(13.2) a	60(6.1) a	71(7.0) a	89(3.3) a	98(1.2) a
DiPel 2X	1.12 kg	17(4.1)	8(5.1) ab	14(5.3) bc	21(8.7) bc	26(6.0) b	32(9.3) b	71(7.6) b	71(5.1) b
XenTari	1.12 kg	12(3.0)	5(2.2) ab	14(5.1) bc	32(14.9) bc	17(4.9) bc	5(1.6) cd	18(3.0) c	27(4.6) cd
MK-244 0.16 EC	0.0084 kg (AI)	16(5.3)	3(2.0) b	11(2.9) bcd	20(8.4) c	3(1.2) d	1(1.0) d	6(1.9) de	8(4.1) f
XenTari R/	1.12 kg								
MK-244 0.16 EC[3]	0.0084 kg (AI)	17(5.1)	10(3.5) ab	19(8.3) b	12(8.5) c	6(2.9) d	5(1.6) cd	16(5.8) cd	19(5.1) de
MK-244 0.16 EC	0.0084 kg (AI)								
R/ XenTari[4]	1.12 kg	18(2.5)	2(1.2) b	2(1.2) d	19(3.7) c	11(3.7) cd	2(1.2) d	5(2.2) e	10(4.5) ef
XenTari[5]	1.12 kg	11(1.9)	8(3.7) ab	5(2.7) cd	11(3.7) b	26(1.9) b	12(2.5) c	19(3.3) c	42(7.5) c

[1]Rates expressed as formulated product unless otherwise indicated (AI).
[2]ANOVA performed on transformed (ARCSIN[SQRT %]) data. Nontransformed means presented. Means within the same column followed by the same letter are not significantly different ($P > 0.05$, Waller-Duncan *K*-ratio *t*-test, *K*-ratio = 100).
[3]Insecticides rotated (R/) every two applications starting with XenTari.
[4]Insecticides rotated (R/) every two applications starting with MK-244 (emamectin benzoate).
[5]Third application skipped. Applied water +X-77 only.

TABLE 2. EFFECTS OF INSECTICIDES ON MEAN PERCENT OF PLANTS WITH DAMAGE RATINGS ≤ 3 AND ≤ 4 IN MATURE HEAD CABBAGE AT CFREC-SANFORD, FL, 1992. DAMAGE RATED ON A SCALE OF 1-6.

		% Plants at Two Levels of Damage (SEM)[2]	
Treatment	Rate per Hectare[1]	DR ≤ 3	DR ≤ 4
Nontreated	—	0 (0.0) d	2 (2.0) e
DiPel 2X	1.12 kg	2 (2.0) d	16 (8.1) e
XenTari	1.12 kg	32 (6.6) b	72 (6.6) bc
MK-244 0.16 EC	0.0084 kg (AI)	62 (11.1) a	92 (5.8) a
XenTari R/ MK-244 0.16 EC[3]	1.12 kg 0.0084 kg (AI)	20 (8.9) bc	44 (14.7) d
MK-244 0.16 EC R/ XenTari[4]	0.0084 kg (AI) 1.12 kg	60 (7.1) a	86 (2.4) ab
XenTari[5]	1.12 kg	12 (4.9) c	56 (12.9) cd

[1]Rates expressed as formulated product unless otherwise indicated (AI).
[2]ANOVA performed on transformed (ARCSIN [SQRT %]) data. Nontransformed means presented. Means followed by the same letter within each column are not significantly different (P >0.05, Waller-Duncan *K*-ratio *t*-test, *K*-ratio = 100).
[3]Alternated every two applications starting with XenTari.
[4]Alternated every two applications starting with MK-244 (emamectin benzoate).
[5]Third application skipped. Applied only water and X-77.

ficacy between the two alternation patterns may have been the result of the significantly (P <0.05) higher reduction in the level of infestation early (7 April) and late (5 May) in the treatment that started with emamectin benzoate. This was supported further by the fact that the last two treatments in the alternation pattern that started with emamectin benzoate was XenTari, which was the weaker of the two insecticides when used alone. XenTari alone was the third most efficacious treatment based on marketability and resulted in consistently low infestation levels. Using XenTari when the infestation level exceeded 5% resulted in the elimination of only the third application. The percent infestation of diamondback moth did not differ significantly (P >0.05) on any date between the XenTari treatments. However, the percentage of harvested plants that were rated ≤ 3 was significantly lower in the treatment where the third application was skipped, suggesting that the third application was important in maintaining control. Disappointing results with DiPel 2X strongly suggested that this diamondback moth population was resistant to *Btk*, especially because *Btk*-resistance in diamondback moth has been documented in central Florida (Leibee & Savage 1992c, Shelton et al. 1993) and suspected in southern Florida (Jansson 1992).

Homestead

The numbers of diamondback moth were unusually high and peaked at 213.7 larvae and pupae per plant in the nontreated check on 16 March (Table 3). All treatments prevented the high numbers that occurred in the nontreated check. Weekly applications of emamectin benzoate and XenTari and the rotational treatment of these two insecticides were most efficacious at reducing populations. All remaining treatments

TABLE 3. EFFECTS OF INSECTICIDES ON NUMBER OF DIAMONDBACK MOTH LARVAE AND PUPAE PER PLANT AT TREC, HOMESTEAD, FL, 1992.

		Sample Date					
		27 Feb	2 Mar	9 Mar	16 Mar	23 Mar	30 Mar
Treatment	Rate per Hectare[1]	Total Diamondback Moth Larvae and Pupae per Plant (SEM)[2]					
Nontreatment	—	43.5(6.1) a	122.3(9.1) a	135.9(12.4) a	213.7(19.6) a	188.3(19.5) a	65.4(7.2) ab
AC 513,696 2X WP	1.12 kg	15.5(1.8) c-e	24.5(2.6) d	25.8(2.2) de	43.5(6.8) cd	59.6(7.9) b-d	45.3(6.2) bc
AC 513,696 48 LC	2.8 liters	20.2(3.3) cd	39.5(4.4) c	37.6(2.8) cd	56.3(6.1) bc	93.8(11.9) b	75.6(7.4) a
Larvo-Bt LC	0.3 liters	38.1(5.4) ab	61.1(5.0) b	54.2(5.0) bc	80.2(6.4) b	81.4(11.8) bc	51.1(8.9) a-c
Larvo-Bt LC +	0.3 liters						
Konsume	7.0 liters	23.9(3.9) bc	64.0(6.0) b	72.5(5.9) b	82.6(7.6) b	70.7(8.4) b-d	52.6(6.4) a-c
AC 513,696 48 LC +	2.8 liters						
Konsume	7.0 liters	12.9(2.9) c-e	21.8(1.8) d	20.8(2.0) d-g	36.2(5.3) c-e	54.3(6.7) cd	56.4(8.1) a-c
DiPel 2X	1.12 kg	8.5(1.3) c-e	19.3(2.2) d	12.9(1.7) e-g	24.3(2.7) c-e	44.3(5.0) d	38.6(5.2) c
MK-244 0.16 EC	0.0084 kg (AI)	0.6(0.3) e	0.1(0.0) e	0.1(0.1) g	0.9(0.3) e	0.8(0.3) e	1.0(0.2) d
XenTari	1.12 kg	2.5(0.5) e	1.3(0.3) e	0.7(0.2) fg	1.1(0.3) e	2.7(0.6) e	2.9(0.5) d
MK-244 0.16 EC R/	0.0084 kg (AI)						
XenTari	1.12 kg	7.3(1.3) de	0.6(0.2) e	0.2(0.1) fg	0.1(0.1) e	0.9(0.3) e	2.1(0.5) d
Mevinphos 4 EC +	0.56 kg (AI)						
Cutlass WP	2.24 kg	14.3(2.0) c-e	16.3(2.0) d	10.8(0.8) e-g	19.4(1.6) de	43.6(4.9) d	57.4(6.1) a-c
Cutlass WP	2.24 kg	19.3(3.8) cd	15.9(1.5) d	21.0(2.6) d-f	28.6(3.2) c-e	51.8(6.4) cd	38.0(4.4) c

[1]Rates expressed as formulated product unless otherwise indicated (AI).

[2]ANOVA performed on 1n-transformed data. Nontransformed means presented. Means within the same column followed by the same letter are not significantly different (P >0.05, Waller-Duncan *K*-ratio *t*-test, *K*-ratio = 100).

were not very efficacious at reducing larval abundance on plants. Emamectin benzoate, XenTari, and their alternation were also the most efficacious at reducing damage to cabbage plants and produced significantly higher (P <0.05) percentages of marketable heads (Table 4). It is interesting to note that maintaining larvae and pupae to 1.0 or less per plant (emamectin benzoate used alone) resulted in only 74% marketability. The diamondback moth population at Homestead was probably *Btk*-resistant because *Bta* (XenTari) was much more effective at reducing numbers and damage than the *Btk*-based insecticides. The addition of mevinphos to Cutlass WP provided no significant (P >0.05) benefit over Cutlass WP alone. The addition of a feeding stimulant (Konsume) to AC 513,696 produced a significant (P<0.05) reduction in larval and pupal numbers over AC 513,696 alone on two dates (2 and 23 March). No significant (P >0.05) reduction of larval and pupal numbers occurred when a feeding stimulant (Konsume) was added to Larvo-Bt. No benefit was observed from the addition of the feeding stimulant to either insecticide based on damage rating and marketability.

Belle Glade

1992 Trial. The numbers of diamondback moth were low (Table 5). Feeding damage on the frame leaves was evident early in the trial. Feeding damage to the wrapper leaves was not evident until the last three weeks of the trial. Diamondback moth den-

TABLE 4. EFFECTS OF INSECTICIDES ON DAMAGE RATING (1-6) AND PERCENT MARKETABILITY OF CABBAGE AT TREC, HOMESTEAD, FL, 1992.

Treatment	Rate per Hectare[1]	Damage Index per Plant (SEM)[2]	% Marketable Heads (SEM)[2]
Nontreated	—	5.1(0.1) a	3(1.8) c
AC 513,696 2X WP	1.12 kg	4.6(0.1) ab	17(3.8) bc
AC 513,696 48 LC	2.8 liters	4.6(0.1) ab	16(3.7) bc
Larvo-Bt LC	0.3 liter	4.6(0.1) ab	17(3.8) bc
Larvo-Bt LC + Konsume	0.3 liter 7.0 liters	4.3(0.1) ab	21(4.2) bc
AC 513,696 48 LC + Konsume	2.8 liters 7.0 liters	4.5(0.1) b	23(4.3) b
DiPel 2X	1.12 kg	4.0(0.1) b	32(4.8) b
MK-244 0.16 EC	0.0084 kg (AI)	2.7(0.1) c	74(4.5) a
XenTari	1.12 kg	2.8(0.1) c	75(4.4) a
MK-244 0.16 EC R/ XenTari	0.0084 kg (AI) 1.12 kg	2.6(0.1) c	75(4.4) a
Mevinphos 4 EC + Cutlass WP	0.56 kg (AI) 2.24 kg	4.3(0.1) b	21(4.2) bc
Cutlass WP	2.24 kg	4.6(0.1) ab	22(4.2) b

[1]Rates expressed as formulated product unless otherwise indicated (AI).
[2]Data subjected to ANOVA. Percentage marketable data were transformed (ARCSIN [SQRT %]). Nontransformed means presented. Means within the same column followed by the same letter are not significantly different (P >0.05, Waller-Duncan *K*-ratio *t*-test, *K*-ratio = 100).

TABLE 5. EFFECTS OF INSECTICIDES ON NUMBER OF DIAMONDBACK MOTH LARVAE AND PUPAE PER PLANT AT EREC, BELLE GLADE, FL, 1992.

		Sample Date				
		10 Mar	20 Mar	25 Mar	1 Apr	13 Apr
Treatment	Rate per Hectare[1]	Diamondback Moth Larvae and Pupae per Plant (SEM)[2]				
Nontreated	—	0.5(0.1) bc	0.3(0.1) bcd	0.9(0.2) a	2.4(0.4) a	2.1(0.6) a
Condor OF	2.34 liter	0.2(0.1) ef	0.2(0.1) cf	0.1(0.1) ef	0.3(0.1) hi	0.6(0.2) c-g
MVP	4.67 liter	0.8(0.1) a	0.3(0.1) cde	0.2(0.1) def	0.3(0.1) ghi	0.2(0.1) g
MK-244 0.16 EC R/	0.0084 kg (AI)					
XenTari	1.12 kg	0.2(0.1) fg	0.2(0.1) c-f	0.3(0.1) bcd	0.1(0.1) i	0.3(0.1) d-g
MK-244 0.16 EC	0.0084 kg (AI)	0.0(0.0) g	0.0(0.0) f	0.1(0.1) ef	0.2(0.1) i	0.3(0.1) efg
Cutlass WP	2.24 kg	0.6(0.1) ab	0.4(0.1) bc	0.5(0.1) bc	1.4(0.3) bc	0.8(0.2) bcd
XenTari	1.12 kg	0.1(0.1) fg	0.3(0.1) c-f	0.1(0.1) ef	0.3(0.1) ghi	0.5(0.2) d-g
Javelin WG	1.12 kg	0.2(0.1) def	0.3(0.1) b-e	0.3(0.1) cde	0.6(0.1) efg	0.4(0.1) d-g
DiPel 2X	1.12 kg	0.4(0.1) cde	0.6(0.1) ab	0.3(0.1) cde	1.0(0.2) cde	0.6(0.1) c-f
Biobit FC	3.5 liter	0.4(0.1) bcd	0.3(0.1) cde	0.3(0.1) cd	1.0(0.2) cd	0.6(0.2) c-f
Thiodicarb 3.2 AF	0.90 kg (AI)	0.2(0.1) efg	0.9(0.2) a	0.5(0.1) b	1.7(0.3) b	1.2(0.3) ab
Thiodicarb 3.2 AF +	0.90 kg (AI)					
DiPel 2X	1.12 kg	0.4(0.1) cde	0.2(0.1) c-f	0.3(0.1) cde	0.8(0.2) def	0.9(0.3) bcd
Esfenvalerate XL	0.055 kg (AI)	0.2(0.1) efg	0.1(0.1) ef	0.2(0.1) def	1.0(0.3) def	1.1(0.3) bc
Esfenvalerate XL +	0.055 kg (AI)					
DiPel 2X	1.12 kg	0.1(0.1) fg	0.2(0.1) c-f	0.1(0.0) f	0.6(0.1) fgh	0.2(0.1) fg
Mevinphos 4 EC	1.12 kg (AI)	0.1(0.1) fg	0.2(0.1) c-f	0.1(0.1) ef	0.1(0.1) i	0.7(0.2) b-e
Mevinphos 4 EC +	1.12 kg (AI)					
DiPel 2X	1.12 kg	0.2(0.1) efg	0.1(0.0) def	0.1(0.0) f	0.1(0.1) i	0.2(0.1) g

[1]Rates expressed as formulated product unless otherwise indicated (AI).

[2]ANOVA performed on 1n (x + 1)-transformed data. Nontransformed means presented. Means within each column followed by the same letter are not significantly different ($P > 0.05$, Waller-Duncan *K*-ratio *t*-test, *K*-ratio = 100). NS = nonsignificant ($P > 0.05$) data.

TABLE 5. CONT'D.

		Sample Date			
		20 Apr	5 May	18 May	29 May
Treatment	Rate per Hectare[1]	Diamondback Moth Larvae and Pupae per Plant (SEM)[2]			
Nontreated	—	2.5(0.3) a	7.4(1.1) ab	3.2(0.5) c	0.7(0.2) ef
Condor OF	2.34 liter	1.1(0.2) d-h	2.1(0.8) ghi	3.0(0.9) de	1.9(0.6) cd
MVP	4.67 liter	1.3(0.2) b-f	6.7(2.0) cde	5.0(1.6) c	4.0(1.3) b
MK-244 0.16 EC R/	0.0084 kg (AI)				
XenTari	1.12 kg	0.9(0.2) h	1.7(0.5) hi	0.7(0.3) g	0.1(0.1) fg
MK-244 0.16 EC	0.0084 kg (AI)	0.8(0.2) h	1.2(0.5) i	0.5(0.2) g	0.4(0.2) g
Cutlass WP	2.24 kg	1.2(0.2) c-g	5.1(1.2) cde	4.9(1.5) c	1.0(0.3) de
XenTari	1.12 kg	1.0(0.2) gh	4.1(0.8) cde	2.2(0.7) de	1.1(0.3) de
Javelin WG	1.12 kg	1.2(0.3) e-h	3.1(0.5) def	2.2(0.5) de	0.7(0.3) ef
DiPel 2X	1.12 kg	1.0(0.2) e-h	3.8(0.8) de	3.8(1.0) cd	1.9(0.6) cd
Biobit FC	3.5 liter	1.6(0.3) b-e	8.2(2.2) bc	6.2(2.8) c	2.6(0.6) bc
Thiodicarb 3.2 AF	0.90 kg (AI)	1.8(0.3) bcd	11.1(2.2) a	9.2(2.2) b	1.0(0.3) de
Thiodicarb 3.2 AF +	0.90 kg (AI)				
DiPel 2X	1.12 kg	1.0(0.2) fgh	3.0(0.6) efg	1.8(0.5) ef	0.2(0.1) fg
Esfenvalerate XL	0.055 kg (AI)	1.8(0.2) ab	20.2(6.3) a	31.0(8.7) a	6.0(2.2) b
Esfenvalerate XL +	0.055 kg (AI)				
DiPel 2X	1.12 kg	1.2(0.2) d-h	5.3(1.0) cd	10.0(2.9) b	8.5(3.0) a
Mevinphos 4 EC	1.12 kg (AI)	0.9(0.2) gh	1.7(0.4) hi	0.8(0.3) fg	0.6(0.2) efg
Mevinphos 4 EC +	1.12 kg (AI)				
DiPel 2X	1.12 kg	1.8(0.3) bc	2.2(0.5) fgh	0.2(0.1) g	0.6(0.3) efg

[1]Rates expressed as formulated product unless otherwise indicated (AI).

[2]ANOVA performed on 1n (x + 1)-transformed data. Nontransformed means presented. Means within each column followed by the same letter are not significantly different (P >0.05, Waller-Duncan *K*-ratio *t*-test, *K*-ratio = 100). NS = nonsignificant (P >0.05) data.

sity did not average above one per plant until after 20 April. Therefore, data from the last three sampling dates provide the best indicator of efficacy.

Emamectin benzoate, emamectin benzoate alternated with XenTari, XenTari, mevinphos, and mevinphos in combination with DiPel 2X treatments produced the lowest numbers of diamondback moth (Table 5) and the highest marketability (Table 6). The addition of DiPel 2X to esfenvalerate and thiodicarb produced cleaner plants when compared with applications of the chemical insecticides alone. Mevinphos, alone or in combination with DiPel 2X, was as efficacious as the emamectin benzoate treatments at reducing numbers and increasing marketability. Thiodicarb alone and esfenvalerate, alone and in combination with DiPel 2X, did not provide significant control. Numbers of diamondback moth produced in these treatments were higher than in the nontreated check in late season, and also the highest numbers produced in the trial. Counts in the nontreated plots declined at the end of the trial, possibly be-

TABLE 6. EFFECTS OF INSECTICIDES ON PERCENT MARKETABILITY OF GREEN CABBAGE AT EREC, BELLE GLADE, FL, 1992.

		% Marketability (SEM)[2]	
Treatment	Rate per Hectare[1]	Wrapper Leaves Attached	Wrapper Leaves[3] Removed
Nontreated	—	8(4.8) d	20(4.1) de
Condor OF	2.34 liters	28(9.5) cd	40(13.5) de
MVP	4.67 liters	13(6.3) d	20(11.5) e
MK-244 0.16 EC	0.0084 kg (AI)		
R/ XenTari	1.12 kg	80(4.1) a	80(0.0) abc
MK-244 0.16 EC	0.0084 kg (AI)	75(5.0) a	85(11.9) a
Cutlass WP	2.24 kg	25(11.9) cd	35(6.5) de
XenTari	1.12 kg	33(13.8) cd	60(17.8) a-d
Javelin WG	1.12 kg	38(16.5) bcd	50(13.5) b-e
DiPel 2X	1.12 kg	25(8.7) cd	45(15.0) cde
Biobit FC	3.5 liters	18(6.3) d	33(8.5) de
Thiodicarb 3.2 AF	0.90 kg (AI)	8(4.8) d	15(2.9)e
Thiodicarb 3.2 AF	0.90 kg (AI)		
+ DiPel 2X	1.12 kg	53(14.9) abc	63(10.3) a-d
Esfenvalerate XL	0.055 kg (AI)	15(8.7) d	23(13.1) e
Esfenvalerate XL	0.055 kg (AI)		
+ DiPel 2X	1.12 kg	15(8.7) d	35(17.6) de
Mevinphos 4 EC	1.12 kg (AI)	58(7.5) abc	83(6.3) ab
Mevinphos 4 EC	1.12 kg (AI)		
+ DiPel 2X	1.12 kg	68(7.5) ab	88(6.3) a

[1]Rates expressed as formulated product unless otherwise indicated (AI).

[2]ANOVA performed on transformed (ARCSIN [SQRT %]) data. Nontransformed means presented. Means within each column followed by the same letter are not significantly different ($P > 0.05$, Waller-Duncan *K*-ratio *t*-test, *K*-ratio = 100).

[3]Marketability rated again after removing no more than three wrapper leaves.

cause the plants were so badly damaged that they were no longer attractive to ovipositing females. Counts in the esfenvalerate and thiodicarb plots also declined at the end of the trial.

The marketability of the heads before trimming (Table 6) appeared to be the best criterion to separate treatments under these conditions of low insect pressure. Emamectin benzoate and emamectin benzoate alternated with XenTari provided the highest percentage of marketable heads. DiPel 2X in combination with thiodicarb provided slightly better control than did the Bt's alone before trimming. The low marketability ratings for the esfenvalerate plots, even in combination with of DiPel 2X, demonstrated the problems of season-long use of this pyrethroid.

The Bt-based insecticides performed poorly at this location. Few differences were observed among the *Btk*-based insecticides in their efficacy at reducing numbers of diamondback moth and levels of marketability. *Bta* was comparable to the *Btk*-based insecticides in this test. Conditions other than insecticide resistance, such as the lengthy intervals between the applications of the Bts, may have contributed, in part, to the poor performance of the Bt-insecticides.

1993 Trial. Diamondback moth pressure was much higher in this trial. Pesticides were applied more regularly except for a rainy period between 15 and 23 May. Populations increased greatly over this period (Table 7). The greater population pressure was probably responsible for the lack of differences in percent marketability among treatments before or after wrapper leaves were removed. Therefore, only one set of marketability values is presented in Table 8.

Emamectin benzoate provided excellent control and out-yielded all other treatments despite the 11-day break in treatments. Esfenvalerate provided good early season control; however, it allowed numbers to rise to damaging levels in late season, an observation also found in 1992. Surprisingly, methamidophos provided better control than the Bt-based insecticides throughout most of the trial and yielded over 70% marketable heads. Plants treated with DiPel 2X and XenTari supported low numbers of diamondback moth in early season, but were severely damaged in late season and had low marketability. XenTari provided better control than DiPel 2X in early season when applied at regular weekly intervals.

In conclusion, emamectin benzoate alone and rotated with *Bta* was very efficacious at controlling diamondback moth. A rotation strategy that started with emamectin benzoate was more efficacious than one that started with *Bta*. The lower efficacy of *Btk*-based insecticides compared with that of *Bta* suggested that these populations were developing resistance to *Btk*, but not to *Bta*, which concurs with Shelton et al. (1993).

Given the history of resistance development in the diamondback moth and the documentation of apparent low levels of resistance to *Bta* in Florida (Shelton et al. 1993), complete reliance on *Bta* for control could result in the rapid development of resistance to *Bta*. For these reasons, resistance management programs for *Bta* and other effective insecticides are needed to delay the onset of resistance. The use of rotation strategies, as demonstrated in this study, should help to delay the development of resistance to all insecticides used in a management program.

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TABLE 7. EFFECTS OF INSECTICIDES ON NUMBER OF DIAMONDBACK MOTH LARVAE AND PUPAE PER PLANT AT EREC, BELLE GLADE, FL, 1993.

		Sample Date			
		Apr 21	Apr 29	May 5	May 11
Treatment	Rate per Hectare[1]	Mean (SEM)[2] Diamondback Moth Larvae and Pupae per Plant			
Nontreated	—	1.7(0.2) ns	0.9(0.2) bc	0.8(0.2) ab	5.2(0.3) a
XenTari	0.56 kg	2.1(0.2)	1.5(0.3) a	1.1(0.2) a	1.6(0.2) c
DiPel 2X	1.12 kg	1.5(0.2)	1.0(0.2) ab	1.1(0.2) a	4.7(0.8) b
MK 244 0.16 EC	0.0084 kg (AI)	1.4(0.2)	0.4(0.1) d	0.5(0.1) c	0.1(0.1) e
Methamidophos 4 E	1.2 kg (AI)	1.6(0.2)	0.6(0.1) cd	0.6(0.1) bc	0.5(0.1) d
Esfenvalerate XL	0.055 kg (AI)	1.6(0.2)	0.5(0.1) d	0.4(0.1) c	1.6(0.2) c
		May 20	May 26	Jun 8	Jun 16
Nontreated	—	15.9(1.5) a	41.2(6.0) a	6.3(1.0) b	0.8(0.3) d
XenTari	0.56 kg	13.5(1.6) b	24.0(2.4) b	3.4(0.6) c	2.0(0.4) b
DiPel 2X	1.12 kg	15.6(2.3) b	29.1(3.7) ab	3.1(0.7) c	1.5(0.3) bc
MK 244 0.16 EC	0.0084 kg (AI)	1.2(0.3) d	3.7(1.1) d	0.8(0.3) d	0.7(0.2) d
Methamidophos 4 E	1.12 kg (AI)	7.1(0.9) c	8.8(1.3) c	0.5(0.2) d	1.1(0.3) cd
Esfenvalerate XL	0.055 kg (AI)	11.3(1.3) b	21.2(2.1) b	32.8(7.0) a	11.8(3.2) a

[1]Rates expressed as formulated product unless otherwise indicated (AI).

[2]ANOVA performed on 1n (x + 1)-transformed data. Nontransformed means presented. Means within each column followed by the same letter are not significantly different (P >0.05, Waller-Duncan *K*-ratio *t*-test, *K*-ratio = 100).

TABLE 8. EFFECTS OF INSECTICIDES ON PERCENT MARKETABILITY OF GREEN CABBAGE AT EREC, BELLE GLADE, FL, 1993.

Treatment	Rate per Hectare[1]	% Marketability (SEM)[2]
Nontreated	—	11(0.7) e
XenTari	0.56 kg	45(0.5) c
DiPel 2X	1.12 kg	23(0.9) d
MK 244 0.16 EC	0.0084 kg (AI)	98(0.2) a
Methamidophos 4 E	1.12 kg (AI)	73(0.5) b
Esfenvalerate XL	0.055 kg (AI)	15(0.4) de

[1]Rates expressed as formulated product unless otherwise indicated (AI).

[2]ANOVA performed on transformed (ARCSIN [SQRT %]) data. Nontransformed means presented. Means within each column followed by the same letter are not significantly different (P >0.05, Waller-Duncan *K*-ratio *t*-test, *K*-ratio = 100).

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ATTRACTION OF FEMALE CABBAGE LOOPER MOTHS (LEPIDOPTERA: NOCTUIDAE) TO MALES IN THE FIELD

PETER J. LANDOLT
United States Department of Agriculture, Agriculture Research Service,
1700 SW 23rd Dr., Gainesville, FL 32604

ABSTRACT

Live male cabbage looper moths, *Trichoplusia ni* (Hubner), used to bait traps in cotton fields, attracted conspecific males and females which were captured in the bucket traps. Females captured in traps baited with males included unmated individuals as well as mated ones, with up to 7 spermatophores in the bursa copulatrix. Cabbage looper moths arrived at cages of males in cotton primarily during the first three hours of the night, beginning at dusk.

Key Words: *Trichoplusia ni*, sex pheromone, traps

RESUMEN

Los machos vivos de la polilla de la col, *Trichoplusia ni* (Hubner), usados para cebar trampas en campos de algodón, atrajeron machos y hembras conespecíficos que fueron capturados en trampas de cubeta. Las hembras capturadas en las trampas cebadas con machos incluyeron individuos apareados y no apareados, con hasta 7 espermatóforos en la bursa copulatrix. Las polillas de la col llegaron a las jaulas de machos en el algodón principalmente durante las tres primeras horas de la noche, a partir del crepúsculo.

Although laboratory and field cage studies indicate that adult males of the cabbage looper moth, *Trichoplusia ni* (Hubner), produce a 3-component sex attractant pheromone, there has been no direct evidence of female attraction to male pheromone in the field. In a flight tunnel, unmated females respond to males, male odor, and solvent extracts of males with upwind oriented flights (Landolt & Heath 1989). A sex pheromone (S-(+)-linalool, para-cresol and meta-cresol) that is attractive to females in a flight tunnel bioassay was isolated and identified from solvent washes of male hairpencils (Landolt & Heath 1989). Female attraction to live males has been observed also in field cages (Lenczewski & Landolt 1991). To date, however, there has been no demonstration of female cabbage looper attraction to natural or synthetic male pheromone under field conditions.

I report here the capture of cabbage looper moths in male-baited traps in the field, as well as the sex ratio of trapped moths and the mating status of trapped females. Also included is the diel activity rhythm of attraction of cabbage looper to caged males in the field. These findings support the results of previous laboratory experiments indicating a male-produced female attractant in this species, and indicate some potential for developing a female attractant for field use.

Materials and Methods

Cabbage looper pupae were obtained from a laboratory colony in Gainesville, Florida, and maintained according to the methods of Guy *et al.* (1985). Pupae were shipped to Fresno, California, and male pupae were placed in 30 x 30 x 30 cm aluminum and plastic screen cages in an open-air garage. Pupae were moved daily to new cages to provide emerged moths of discrete age groups. Males in cages were provided a 20% aqueous solution of a mixture of honey and sucrose in a 1:3 ratio on cotton. Water jars were placed on paper toweling on all cage tops to provide a continuous supply of water for the moths.

The trapping test was conducted during June and July 1992 in commercial cotton fields in the San Joaquin Valley of central California. Bucket traps, modeled after the design of Sharma *et al.* (1971), were made from 5-gallon (18.9 liter), nearly cylindrical, black plastic buckets (35.6 cm tall, 26.7 cm wide at the bottom, and 29.2 cm wide at the top). Four circular holes (12.7 cm diam) were cut equidistant in the side of each bucket, 0.5 cm from the bottom of the bucket, and were fitted with screen cones to allow access of attracted moths into the bucket. The screen cones had an inside hole diam of 3 cm. The top of the bucket was covered with clear plastic held in place with an elastic band. Baited traps contained a cylindrical screen cage (7×10 cm) with a wet cotton wick and 5 male cabbage looper moths placed at the center of the bottom of the bucket. Unbaited traps contained the same small cages with wet cotton wicks and no male cabbage looper moths.

Traps were suspended from wire hangers on wooden stakes so that the bottom of the bucket and the cages of males in buckets were near the top of the cotton canopy (about 40 cm). Traps were placed 10 ± 0.5 m apart in cotton fields. On three different days, twenty traps were set up, with 10 baited and 10 unbaited traps. On a fourth day, 10 traps (five unbaited and five baited) were set up, providing a total of 35 trap replicates. Traps were baited with cages of males late in the afternoon and were checked the following day for captured moths. Each captured female moth was dissected to determine the number of spermatophores in the bursa copulatrix (an indication of the number of matings).

Attraction of moths to male cabbage loopers was also monitored visually by using a night vision pocket scope (Nite-eye™, Varo, Inc., Garland, TX). On three nights, a cage of 15 male cabbage loopers was watched continuously, from 30 min before dusk to 30 min after dawn, for visits by moths. The different species of moths known to be in the field, cabbage looper, *Helicoverpa zea* (Boddie), *Spodoptera exigua* (Hubner), and *Apantesis prolata* were easily distinguishable in flight at night using the night vision pocket scope, by their size and reflectance. Occasional netting of arriving moths confirmed that they were indeed cabbage looper moths.

RESULTS

Significant numbers of both male and female cabbage looper moths were captured in the traps baited with live males, while no moths of any species were captured in control traps. Numbers of moths captured per night in male-baited traps ranged from 0 to 59. Means of 4.5 ± 1.9 (SEM) males ($t=2.37$, $df=34$, $p=0.02$) and 3.0 ± 0.6 females ($t=5.4$, $df=34$, $p<0.01$) were captured per trap per night in male-baited traps. Of the 105 females captured in male-baited traps, nearly one half were unmated, without spermatophores in the bursa copulatrix (Fig. 1). Mated females in traps contained from one to 7 spermatophores in the bursa copulatrix, indicating mating frequencies from 1 to 7 times. A similar pattern of spermatophore numbers was found in a smaller sample (24) of females captured in adjacent fields in traps baited with the female pheromone Z-7-dodecenyl acetate (Fig. 1), with mating frequencies up to 8. I assumed that female cabbage looper moths captured in traps baited with female pheromone were attracted to males releasing pheromone at the trap lure, as reported by Birch (1977). It is also possible that males captured in male-baited traps were attracted in part to pheromone released by attracted females.

In the three nights of observations of cages of male *T. ni* in a cotton field, 182 visits were noted of moths that appeared to be cabbage looper moths (28 on night 1, 32 on night 2, and 122 on night 3). One additional moth of an undetermined species of Sphingidae approached a cage of males. On all three nights of observations, cabbage looper moth visits to the cage of males began after sunset (near 2000 hour), but 30 min to 45 min before it was too dark to see without the aid of the night vision scope. Approaching moths were seen and followed from up to 10 m away from the cage early in the evening. Most moth visits at the cage occurred early in the night (Fig. 2), from 2000 to 2200 hour, with very little activity after midnight.

DISCUSSION

These experiments constitute the first documentation of female cabbage looper moth attraction to males in the field, although it is likely that captures of females in traps baited with female pheromone (Birch 1977) were also a result of female attraction to males. The capture of females in male-baited traps indicate that the observed attraction of females to males, male extracts, and synthetic male pheromone in laboratory studies (Landolt & Heath 1989, 1990) is indeed an aspect of a mate-finding strategy that occurs under natural conditions in the field. The time of night that cab-

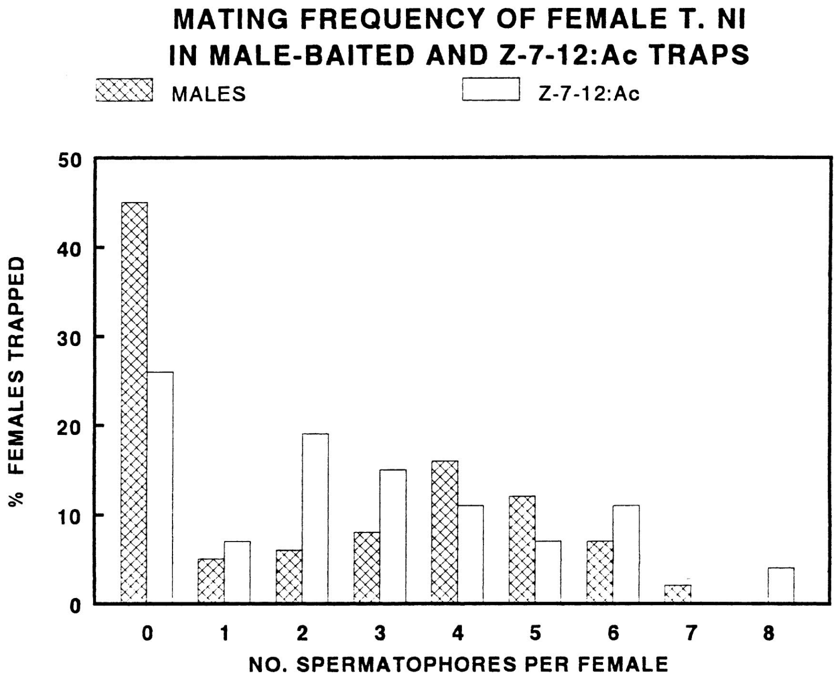

Fig. 1. Percentages of female cabbage looper moths captured that possessed different numbers of spermatophores in the bursa copulatrix. Crosshatched bars are for females captured in bucket traps baited with 5 live males. Open bars are for females captured in Universal™ moth traps baited with the female pheromone, Z-7-dodecenyl acetate.

bage looper moths visited males (Fig. 2) matches the pattern of female visits to males in a large field cage (Lenczewski & Landolt 1991). This early night activity period is distinct from the peak period of male attraction to females and of female calling later in the scotophase (Lenczewski & Landolt 1991; Shorey 1966).

Capture of female cabbage looper moths in traps baited with males provides incentive to develop a synthetic lure for females based on male pheromone compounds. Results of this trapping test indicate that such a lure should function to attract males, unmated females and females that have already mated. If a synthetic lure based on male pheromone is developed, it could provide a useful tool for sampling females on field crops and possibly also for population suppression.

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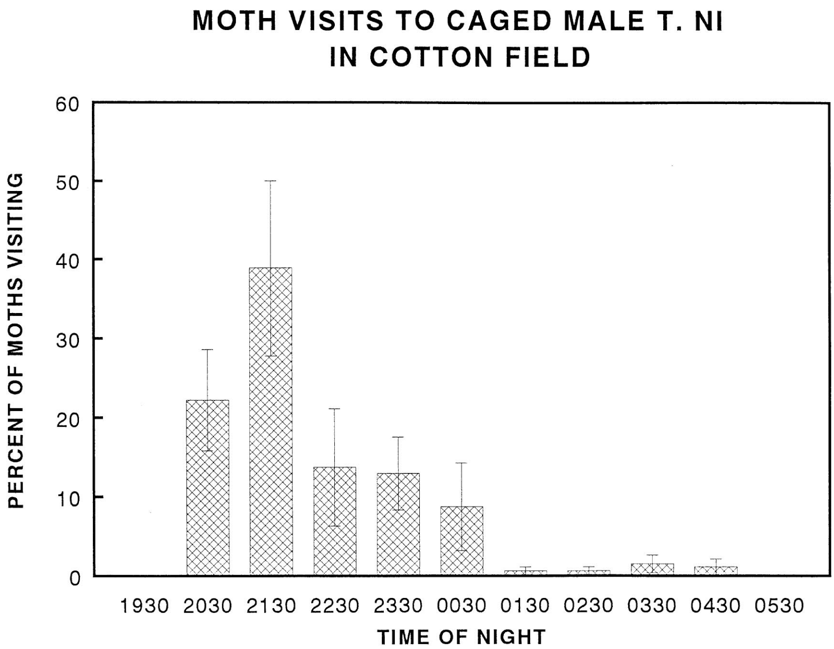

Fig. 2. Mean (± SEM) percentages of cabbage looper moth visits to cages containing 15 live cabbage looper males in a cotton field at different times of the night.

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PHEROMONAL MEDIATION OF ALARM IN THE EASTERN YELLOWJACKET (HYMENOPTERA: VESPIDAE)

P. J. LANDOLT[1], R. R. HEATH[1], H. C. REED[2], AND K. MANNING[2]
[1]Insect Attractants, Behavior, and Basic Biology Research Laboratory
Agricultural Research Service, U.S.D.A.
P.O. Box 14565, Gainesville, FL 32604

[2]Department of Biology, Oral Roberts University,
7777 S. Lewis Ave., Tulsa, OK, USA, 74171.

ABSTRACT

Eastern yellowjacket, *Vespula maculifrons* (Buysson), workers exhibited alarm responses to a target sphere treated with an extract of conspecific workers or an extract of the wasp sting apparatus. Workers of *Vespula squamosa* also responded to extracts of the sting apparatus of *Vespula maculifrons*, indicating some cross reactivity of their alarm pheromones. N-3-methylbutylacetamide, a known alarm pheromone of the southern yellowjacket, *Vespula squamosa* (Drury), was found in the extract of the eastern yellowjacket venom sac and also elicited alarm in worker *V. maculifrons*, although only when presented at an unnaturally high dose.

Key Words: Insecta, social, communication, defense, behavior, wasp

RESUMEN

Las obreras de la avispa del este, *Vespula maculifrons* (Buysson), mostraron respuestas de alarma ante un blanco contituído por una esfera tratada con un extracto de obreras conespecíficas o con un extracto de su aparato picador. Las obreras de *Vespula squamosa* (Drury) también respondieron a los extractos del aparato picador de *V. maculifrons*, indicando cierta reacción cruzada de sus feromonas de alarma. La N-3-metilbutilacetamida, una conocida feromona de alarma de la avispa del sur, *V. squamosa*, fue encontrada en el extracto del saco del veneno de la avispa del este y además provocó alarma en las obreras de *V. maculifrons*, aunque solamente cuando se presentó a una dosis más alta que la natural.

Several species of social wasps (Vespidae) in different genera are known to use pheromones to communicate alarm at the nest site evoking recruitment, attraction, and/or attack. Alarm responses to venom or extracts of venom have been demonstrated for the yellowjackets *Vespula vulgaris* (L.), *Vespula germanica* (Fab.) (Maschwitz 1964), *Vespula squamosa* (Drury) (Landolt & Heath, 1987) and *Dolichovespula saxonica* (Fab.) (Maschwitz 1984), the hornet *Vespa crabro* L. (Veith et al. 1984), the paper wasps *Polistes canadensis* (L.) (Jeanne, 1982), *Polistes exclamans* Viereck and *Polistes fuscatus* (F.) (Post et al 1984), and the polybiine *Polybia occidentalis* (Olivier) (Jeanne, 1981). Despite these reports, it is not known if pheromonal communication of alarm is widespread within the Vespidae, or if most social wasps rely primarily on substrate vibration to communicate alarm (Akre & MacDonald 1986).

Alarm pheromones have been identified from only two species of Vespidae; both isolated from venom. Veith et al. (1984) isolated and identified methyl-3-butene-2-ol

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from venom of *Vespa crabro* and demonstrated that it elicits wing buzzing, defense flights, and departure from the nest in worker *V. crabro*. Heath & Landolt (1988) identified N-3-methylbutylacetamide as an alarm pheromone of the southern yellowjacket, *V. squamosa*, and demonstrated attraction and attack responses in worker *V. squamosa*. This compound was found by Aldiss (1983) in extracts of venom sacs of *V. vulgaris*, but its function in that species has not been experimentally tested.

We report here pheromonal mediation of alarm and attack by workers of another species of yellowjacket, *Vespula maculifrons* (Buysson), as a response to a solvent extract of conspecific worker wasps and an extract of the worker sting apparatus, including the venom sac. We also demonstrated alarm and attack by *V. squamosa* workers in response to extract of *V. maculifrons* sting apparatus, indicating some cross reactivity and overlap in the chemical makeup of alarm pheromones of the two species. Subsequently, we confirmed the presence of N-3-methylbutylacetamide, an alarm pheromone of *V. squamosa* (Landolt & Heath 1987) and venom component of *V. vulgaris* (Aldiss 1983), in the venom sac of *V. maculifrons* workers.

MATERIALS AND METHODS

Colonies of *V. maculifrons* and *V. squamosa* used in this study were located in Tulsa, Oklahoma and Gainesville and Sarasota, Florida. All were terrestrial, or underground, nests. Voucher specimens have been retained in the collection of the first author (PJL).

Wasps used for extracts were either collected by placing a glass jar over the nest entrance, or were vacuumed from colony entrances, using a device similar to that of Akre et al. (1973). The jar or collector trap with wasps was then placed in an insulated chest with dry ice. Wasps were stored at -60°C until extraction (1-30 d). Whole wasp extracts were obtained by grinding groups of 50 yellowjackets in 10 ml methylene chloride, using a mortar and pestle. Extract was then pipetted into a glass vial for storage in a freezer at -10°C. Sting apparatuses for extracts were removed from wasp abdomens by pulling the sting out with forceps and disconnecting the rectum from the sting chamber. This included the sting, sting chamber, venom and Dufour's glands and the venom sac. Groups of 100 were placed in one ml of methylene chloride for one to 2 h. Solvent extracts were then pipetted into clean glass vials and were stored at -10°C until used in bioassays. Sting apparatus extract aliquots (measured in wasp-equivalents) were applied as 200 µl amounts on 5.5 cm diam filter papers in bioassays.

Chemical Analysis

Extracts of the venom sac were prepared as described above, using six groups of 5 venom sacs placed in vials containing 200 ul solvent. Gas chromatographic analysis was conducted using a Hewlett Packard 5890 GC with a flame ionization detector, a splitless capillary injector, and a 50 m (0.25 mm i.d.; 0.25 µm film of BP-1) apolar fused silica capillary column (Supelco Corp., Belfonte, PA). Helium was used as the carrier gas at a linear flow rate of 18 cm per sec. The structure of the principal compound evident in the chromatograms (Fig. 1) was confirmed with methane chemical ionization mass spectra (CI-MS), using a Nermag Model R1010 mass spectrometer.

Alarm Bioassays

Four experiments were conducted to test for alarm and attack by worker yellowjackets in response to extracts or to candidate alarm pheromone. Two experiments us-

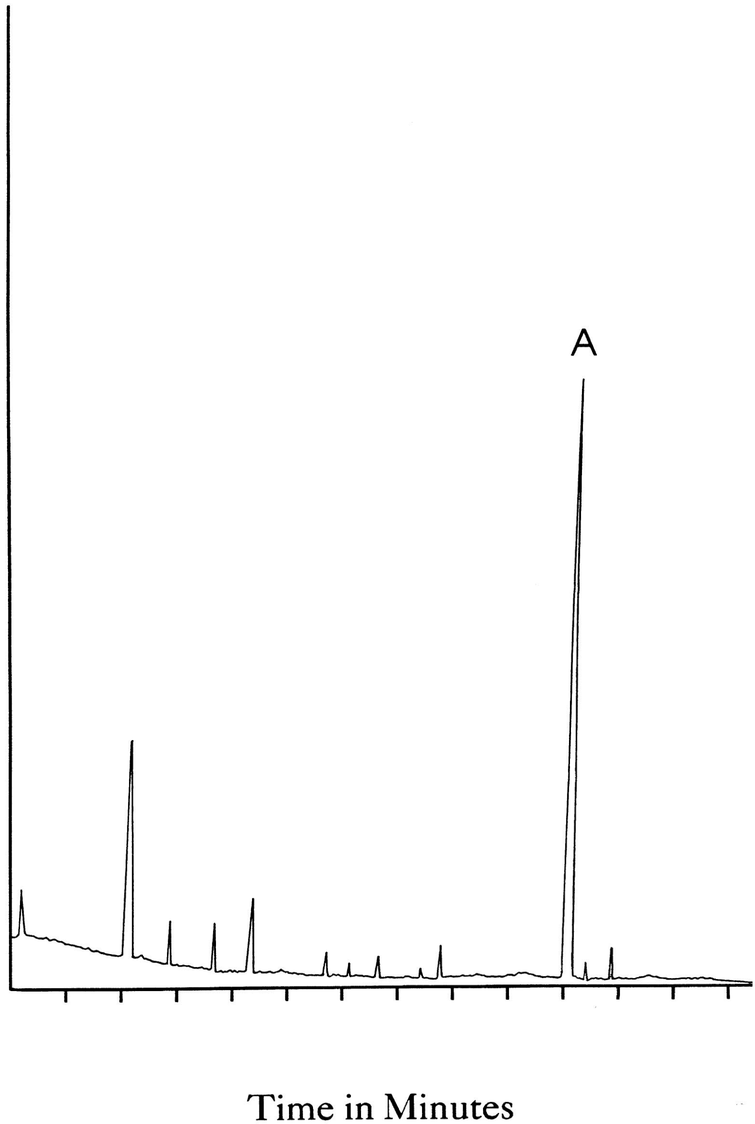

Fig. 1. Chromatogram of a methylene chloride extract of the sting apparatus of worker *Vespula maculifrons*. Peak A is N-3-methylbutylacetamide, confirmed by GC-MS.

ing different assay designs were conducted initially to assess *V. maculifrons* alarm responses to an extract of conspecific workers and to an extract of conspecific worker sting apparatuses. The third experiment tested for heterospecific alarm responses of *V. squamosa* workers to the sting apparatus extract of *V. maculifrons*. Lastly, an experiment was conducted to determine if *V. maculifrons* workers respond to N-3-methylbutylacetamide, which was found in venom sac extracts of both species. For most colonies one-minute counts were made of numbers of wasps entering and exiting the colony as a relative assessment of colony size and activity (Malhalm et al. 1991). Colony responses to disturbances and to alarm pheromone are likely to be dependent in part on colony size.

In the first experiment, a whole *V. maculifrons* wasp extract was tested. Forty-three wasp-equivalents of extract (8.6 ml methylene chloride) were applied to a 5.5 cm diam filter paper in a glass petri plate 6-8 cm upwind of the colony entrance (as per Maschwitz 1964) and seven wasp-equivalents of the whole wasp extract (1.4 ml) were placed on a 5.5 cm diam filter paper on a 14 cm diam target sphere 0.5 cm upwind of the entrance and 0.5 m above ground on a wooden stake. Counts were then made of numbers of wasps hitting the target for a 5 min period following application of the extract. Similar applications of methylene chloride were conducted first as a control. This experiment was conducted 6 times, using 2 colonies of eastern yellowjackets, during October and November 1991 in Tulsa, Oklahoma. Bioassays were conducted between 1100 and 1600 hrs, with full sun and temperatures of 24-25°C.

In the second experiment, *V. maculifrons* sting apparatus extract was applied to 5.5 cm diam filter papers placed directly on the top of the target only, as described by Landolt & Heath (1987). The target (14 cm diam black sphere) was coated with an adhesive (Tangle Trap, The Tanglefoot Company, Grand Rapids, Michigan, USA) to capture wasps contacting the target. The target sphere was placed on a wooden dowel 0.2 m above ground and was positioned one m upwind of the entrance of a *V. maculifrons* colony. Treatments consisted of a solvent control and extract dosages of 1, 5, and 25 wasp equivalents in 200 µl methylene chloride. Wasps captured on the target adhesive were counted 2 min after application of the extract sample to the filter paper. Each sphere was removed from the test area at 2 min to end the test. A test series (consisting of the 4 treatments in increasing dosage order) was conducted three times on 2 different colonies in Gainesville, Florida. Spheres were not reused following an assay.

In the third experiment, dosages of *V. maculifrons* sting apparatus extract were tested for responses by worker *V. squamosa*, using the same bioassay procedure as in the second experiment. Treatments consisted of a solvent control and extract dosages of 1, 5, and 25 wasp equivalents. The target sphere was positioned one m upwind of the entrance of a *V. squamosa* colony entrance and numbers of wasps captured on the target adhesive were counted 2 min after application of the extract. This experiment was conducted seven times in November and December 1992, using 3 colonies of *V. squamosa* in Gainesville and Sarasota, Florida.

The fourth experiment was a test for stimulation of alarm in *V. maculifrons* workers by synthetic N-3-methylbutylacetamide. Synthesis and purification procedures are reported in Heath & Landolt (1988). Dosages were applied in 200 µl aliquots of hexane to 5.5 cm diam filter papers placed on the top of 14 cm diam black spheres coated with Tangle Trap. Spheres were positioned one m upwind of a *V. maculifrons* colony entrance. For each replicate, a series of treatments were tested, with increasing dosages of N-3-methylbutylacetamide (0, 2, 10, and 50 µg, or 0, 23, 120, and 600 wasp equivalents). Numbers of wasps contacting the sphere and captured in the adhesive were counted 2 min after each treatment. Spheres that captured wasps were replaced between treatment dosages tested. This experiment was conducted 3 times on different days during November 1992, using one colony of *V. maculifrons*.

Statistical analyses of the responses of wasps to bioassay treatments were determined for all 4 experiments using the Mann-Whitney U test as described in Spiegel (1991).

RESULTS

Workers from colonies of eastern yellowjackets contacted a target sphere when methylene chloride extracts of conspecific workers were placed both near the colony entrance and on the target sphere, and did not hit the sphere when the solvent control was applied (significantly different at $p \leq 0.01$, $z=2.9$) (Table 1). Similar results were obtained when sting apparatus extracts were placed only on a filter paper on the target sphere, and not near the entrance (Table 2). Again, wasps hit the sphere and were captured in the adhesive in response to the extract (at 5 wasp equivalents) and not in response to the solvent control (significantly different at $p \leq 0.05$, $z=1.96$).

Workers of *V. squamosa* also responded to 25 wasp equivalents of sting apparatus extract of *V. maculifrons* workers with circling flights and direct hits on the treated target sphere (significantly greater than the control at $p \leq 0.05$, $z=2.05$) (Table 2).

One principal peak was evident in chromatograms of *V. maculifrons* venom sac extract, with a Kovats Index (Kovats, 1965) of 1102 (Fig. 1). This peak co-eluted with that of synthetic N-3-methylbutylacetamide, an alarm pheromone of the southern yellowjacket (Heath & Landolt, 1988). The structure of the compound in *V. maculifrons* sting apparatus extract was confirmed to be N-3-methylbutylacetamide with chemical ionization mass spectra. Quantitative gas chromatographic analysis of sting apparatus extract of *V. maculifrons* workers from 6 batches of 5 wasps showed an average (± SEM) of 84.2 ± 17.7 ng N-3-methylbutylacetamide extracted per wasp.

Eastern yellowjackets responded to synthetic N-3-methylbutylacetamide in the bioassay employed with direct hits on the target sphere and did not respond to the solvent controls. Numbers captured in response to the 50 µg dosage were significantly greater than those responding to the control ($p \leq 0.05$, $z=1.96$) (Table 3).

TABLE 1. ALARM RESPONSE (HITS ON TARGET) OF EASTERN YELLOWJACKETS TO DOSAGES OF CONSPECIFIC WHOLE WASP EXTRACT PLACED SIMULTANEOUSLY NEAR THE NEST ENTRANCE (43 WASP EQUIVALENTS) AND ON A TARGET SPHERE 0.5 M FROM THE NEST ENTRANCE (7 WASP EQUIVALENTS), AND TO SOLVENT CONTROLS. DURATION OF ASSAY WAS 5 MIN. AI (ACTIVITY INDEX) IS WASPS ENTERING AND EXITING THE COLONY PER MINUTE.

Trial	Date	AI	Treatment	No. Hits
1	29 Oct 91	42	Control	0
			Extract	12
2	2 Nov 91	11	Control	0
			Extract	36
3	2 Nov 91	11	Control	0
			Extract	109
4	3 Nov 91	53	Control	0
			Extract	8
5	4 Nov 91	32	Control	0
			Extract	82
6	4 Nov 91	32	Control	0
			Extract	3

TABLE 2. ALARM RESPONSE (HITS ON SPHERE) OF *V. MACULIFRONS* OR *V. SQUAMOSA* WORKERS TO DOSAGES OF *V. MACULIFRONS* VENOM SAC EXTRACT APPLIED TO A TARGET SPHERE ONE M FROM A COLONY ENTRANCE. DURATION OF ASSAY WAS 2 MIN. AI (ACTIVITY INDEX) IS THE NUMBER OF WASPS ENTERING AND EXITING THE COLONY PER MINUTE.

			Dosage in Wasp Equivalents			
Trial	Date	AI	0	1	5	25
			V. maculifrons			
1	26 Dec 87	-	0	0	4	168
2	18 Nov 92	182	0	0	8	0
3	19 Nov 92	148	0	0	1	11
			V. squamosa			
1	18 Nov 92	40	0	7	1	0
2	19 Nov 92	44	0	0	1	7
3	23 Nov 92	98	0	0	1	1
4	14 Dec 92	240	0	-	-	0
5	14 Dec 92	240	0	-	-	2
6	16 Dec 92	300	1	-	-	7
7	21 Dec 92	240	1	-	-	27

DISCUSSION

The results of these experiments indicate that *V. maculifrons* workers possess an alarm pheromone associated with the sting apparatus that elicits attraction and attack. The behavior of eastern yellowjackets that we observed in response to wasp and sting apparatus extracts was qualitatively similar to that reported for the southern yellowjacket (Landolt & Heath 1987). These included circling flights (either around the nest entrance or the target spheres), casting and zigzagging upwind flight patterns towards the target, and direct flights to contact the target. Most responding wasps came from the nest entrance and foragers returning to the nest did not appear to respond to the extracts. In these assays, only the numbers of wasps trapped in the target adhesive were quantified. However, in all cases, this appeared to be the end result of attraction and attack; typical of alarm responses in other social wasps.

Numbers of wasps hitting the target sphere in response to a 5 wasp-equivalent dosage of extract in these studies were variable. This may have been due in part to differences in colony size, as indicated by the range of activity indices, as well as general activity levels at the nest entrance. We also experienced problems with changing wind direction in some experiments with a target placed one m from the nest entrance. An attempt was always made to position the sphere upwind of the entrance so that treatment odors would be carried to the nest entrance. Wind direction shifted during the course of some assays, however.

Observed alarm responses of *V. squamosa* workers to *V. maculifrons* extract suggest overlap in pheromone chemistry between the two species. The chemical analyses of *V. maculifrons* venom sac extract revealed the presence of N-3-methylbutylacetamide, a known alarm pheromone of *V. squamosa* (Heath & Landolt 1988). This compound was the principal volatile found in those extracts of *V. maculifrons*. Subsequent

TABLE 3. ALARM RESPONSE (HITS ON SPHERE) OF *V. MACULIFRONS* WORKERS TO DOSAGES OF N-3-METHYLBUTYLACETAMIDE APPLIED TO A TARGET SPHERE ONE M FROM A COLONY ENTRANCE. DURATION OF ASSAY WAS 2 MIN. AI (ACTIVITY INDEX) IS THE NUMBER OF WASPS ENTERING AND EXITING THE COLONY PER MINUTE.

			Dosage in Micrograms			
Trial	Date	AI	0	2	10	50
1	22 Oct 92	60	0	0	5	11
2	27 Oct 92	62	0	13	0	29
3	29 Nov 92	50	0	0	0	38

bioassay results demonstrated that this compound elicited attraction and attack in conspecific workers when applied to target spheres.

The doses of N-3-methylbutylacetamide needed to evoke eastern yellowjacket alarm responses in our bioassay were much higher than that found in wasp venom sacs, indicating that additional chemicals from the venom sac, or possibly the Dufour's gland, may be used by *V. maculifrons* to communicate alarm. In analyses of venom sac extracts, an average of 84.2 nanograms N-3-methylbutylacetamide was found per wasp (Fig. 1). However, while only about 420 ng of this compound should have been present in the 5 wasp equivalent samples of extract that elicited an alarm response (Table 2), much more of the synthetic N-3-methylbutylacetamide (2 to 50 ug) was required to stimulate alarm behavior (Table 3). Although no other alarm pheromone compounds have been isolated from yellowjackets, it seems likely that a multicomponent alarm pheromone may exist in *V. maculifrons*.

N-3-methylbutylacetamide was also found by Aldiss (1983) in the venom of *V. vulgaris* and may be an alarm pheromone of this species also. The sharing or overlap of chemicals comprising alarm pheromones is not unusual, possibly due to the limited complexity of hydrocarbon compounds in the required range of volatility for alarm pheromones (Wilson & Bossert 1963) and the absence of a need for species or functional specificity (privacy referred to by Holldobler & Wilson 1990). *V. squamosa* is considered to be a member of a different species group or genus (Duncan 1939; Carpenter 1987) than *V. maculifrons*. However, since *V. squamosa* is a facultative social parasite of *V. maculifrons* (MacDonald & Matthews, 1975), it may be particularly adaptive for *V. squamosa* to share and respond to the same alarm pheromone as its host, since workers of both species may occupy the same nest. Additional work is needed to determine if N-3-methylbutylacetamide is present in the venom of other Vespidae and if, indeed, it functions as an alarm pheromone among other species of yellowjackets and social wasps.

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A SURVEY OF THE URBAN PEST ANTS (HYMENOPTERA: FORMICIDAE) OF PENINSULAR FLORIDA

JOHN H. KLOTZ[1], JOHN R. MANGOLD[2], KAREN M. VAIL[1], LLOYD R. DAVIS, JR.[1] AND RICHARD S. PATTERSON[1]

[1]United States Department of Agriculture - Agriculture Research Service, Household Insects & Imported Fire Ants Research Unit, Gainesville, FL 32608

[2]The Terminix International Co. L.P., 25400 U.S. Highway 19 N., Suite 259 Clearwater, FL 34623

ABSTRACT

A one year survey was conducted with structural pest control employees of Florida to determine the kinds of ants and types of ant problems confronted in both commercial and household pest control. Eight species of ants were identified as key pests in Florida. Of these, the most common were *Solenopsis invicta* Buren - 14%, *Tapinoma melanocephalum* (F.) - 14%, *Paratrechina longicornis* (Latreille) - 14%, *Camponotus abdominalis floridanus* (Buckley) - 12%, *Monomorium pharaonis* (L.) - 11%, *Camponotus tortuganus* Emery - 8%, *Pheidole megacephala* (F.) - 7% and *Paratrechina bourbonica* (Forel) - 4%. More than twenty-five other species of ants which were occasional invaders were also collected in the survey. Customer complaints, nest locations, and treatment strategies for pest ants are also described.

Key Words: Urban pest control, house-infesting, treatment strategies, ant baits

RESUMEN

Una encuesta de un año fue llevada a cabo con empleados de control de plagas estructurales de la Florida para determinar los tipos de hormigas y de problemas causados por estas que eran confrontados por el control comercial y doméstico de plagas. Ocho especies de hormigas fueron identificadas como plagas claves en la Florida. De estas, las más comúnes fueron *Solenopsis invicta* Buren-14%, *Tapinoma melanocephalum* (F)-14%, *Paratrechina longicornis* (Latreille)-14%, *Camponotus abdominalis floridanus* (Buckey)-12%, *Monomorium pharaonis* (L)-11%, *Camponotus tortuganus* Emery-8%, *Pheidole megacephala* (F.)-7%, y *Paratrechina bourbonica* (Forel)-4%. También más de veinte y cinco especies de hormigas invasoras ocasionales fueron colectadas en la encuesta. Las quejas de los clientes, localizaciones de los nidos y estrategias de tratamiento para las hormigas plagas son también descritas.

Pest ants in the urban environment have a significant economic impact both on the pest control industry and the general public. In the National Home and Garden Pesticide Use Survey (Whitmore et al. 1992) ants were ranked as the number one pest problem of households, even surpassing cockroaches. However, their economic importance is overshadowed by our lack of information on both biology and control for many of these pest ants. A few species are well studied: fire ants because of their medical and agricultural impact (Banks 1990); Pharaoh ants, which are major household pests and can act as disease vectors in hospitals (Williams 1990); and carpenter ants, which are important wood-destroying organisms (Akre & Hansen 1990). We need to learn more about numerous other pest species with the goal of designing more effective control programs.

Hedges (1992) and Thompson (1990) on a national scale and Smith (1965) for the eastern United States describe common structure-infesting ants. On a regional scale, a comprehensive list of the ants of Florida (Deyrup et al. 1989) reports geographic distribution of ant species by county, but only two small surveys report on structure-infesting ants in Florida (Bieman & Bloomcamp 1987; Bieman & Wojcik 1990).

Our goal in this study was to conduct a year-long survey of the structure-infesting pest ants of peninsular Florida to determine which species of ants pest control employees (PCEs) are being called upon to control, both in commercial accounts, such as hotels and apartment complexes, and private accounts, such as single-family dwellings.

We conducted a survey that consisted of identifying ants sent to us by PCEs (Terminix). The PCEs returned a questionnaire with each ant sample. We were able to determine the relative frequency of occurrence of urban pest ants, in addition to several key points about the infestations caused by these ants. More importantly the information gleaned from this study offers direction for future research with urban pest ants. Our findings indicate several species which are economically significant, but have not yet been studied.

MATERIALS AND METHODS

This survey was designed to last one year (January 1, 1993 -December 31, 1993). Thirty-one pest control offices of Terminix International Co. located throughout the state were notified by mail of the survey along with instructions for collecting specimens and completing survey questionnaires. Technicians were directed to collect specimens and complete questionnaires from each site of infestation when responding to a customer complaint for ants. Pest control offices were supplied with isopropyl alcohol, plastic whirl-pak bags, 7-dram, snap-top, plastic vials and preaddressed, padded envelopes for mailing specimens to us. One of us (LDJ) identified specimens with an Olympus binocular dissecting microscope, using the following taxonomic keys: Creighton (1950), Bolton (1979), Trager (1984, 1988), Deyrup et al. (1985), Naves (1985), Johnson (1988), Snelling (1988), and Hölldobler & Wilson (1990).

RESULTS AND DISCUSSION

The total number of samples identified was 810. Response was heaviest in four major metropolitan areas: Daytona/Orlando (Region I), Tampa Bay (Region II), Sarasota/Ft. Myers (Region III) and greater Miami (Region IV). Of this total, 80% consisted of eight common species (Table 1). Of these eight species within the four regions, carpenter ants (20%) were the most frequently encountered; however, they were represented predominantly by two different species [*Camponotus abdominalis floridanus* (Buckley), *C. tortuganus* Emery], while each of the other six common pest ants were represented by a single species. The red imported fire ant (14%), *Solenopsis invicta* Buren, which is a significant medical and agricultural pest, was common in our survey, indicating its importance in urban situations as well. Equally abundant was the ghost ant (14%), *Tapinoma melanocephalum* (F.), and crazy ant (14%), *Paratrechina longicornis* (Latreille). The Pharaoh ant (11%), *Monomorium pharaonis* (L.), was next in abundance and, along with the red imported fire ant, is probably the best studied of all eight species with respect to its control. A big-headed ant (7%),

TABLE 1. COMMON ANT SPECIES AND THEIR PERCENT FREQUENCY FOR EACH OF THE FOUR REGIONS SAMPLED AND FOR ALL REGIONS COMBINED (N = 667).

Species	Region I	Region II	Region III	Region IV	Overall
Camponotus abdominalis	15	14	10	12	12
Camponotus tortuganus	0	6	10	11	8
Monomorium pharaonis	9	13	12	8	11
Paratrechina bourbonica	6	4	4	2	4
Paratrechina longicornis	8	19	10	14	14
Pheidole megacephala	6	2	5	13	7
Solenopsis invicta	20	14	21	6	14
Tapinoma melanocephalum	8	14	10	21	14
Other species	28	14	18	13	16

Pheidole megacephala (F.), was next to the last in abundance. In several locations (Boynton Beach, Port Charlotte, Ft. Myers and Ft. Lauderdale) extensive infestations of *P. megacephala* were found around exterior building perimeters, ornamental plant bases, sidewalks and driveways. Deyrup (1991a) reports on a huge extended colony at one site on Key Largo. Owners of infested structures typically complained of finding hundreds of dead, dying and live ants inside daily. Finally, *Paratrechina bourbonica* (Forel) (4%) was the least abundant. Little is known about control for this last ant pest. Numerous other occasional ant pests made up the remaining 20% of the species, and consisted of many ants not commonly encountered in structural pest control (Table 2).

In a similar survey that we conducted in New Jersey (Klotz et al. 1994), carpenter ants were also the most common ant pest. Carpenter ants in the Pacific Northwest (Furniss & Carolin 1977) and in the northeastern part of the U.S. (Fowler 1983) are considered as important, if not more so, than termites as structural pests. In a survey of the urban ants of California, Knight & Rust (1990) ranked carpenter ants as fourth and the fire ant, *Solenopsis xyloni* McCook, second in frequency. Recognizing the limited amount of information on the extent of damage caused by carpenter ants, we feel they are making a significant economic impact on a national scale.

Carpenter ants, ghost ants, and Pharaoh ants are primarily problems indoors, but a significant proportion of all three are found outdoors (Fig. 1). Of particular interest are Pharaoh ants, which in the past have been considered exclusively indoor pests. In addition to our survey, however, Knight & Rust (1990), Haack (1991) and Oi et al. (1994) showed them to be foraging outdoors, with the latter two authors effectively controlling them with outdoor baiting.

It is a well known fact that carpenter ants have cryptic nesting habits, making their nests very difficult to find. For the majority of the other ant species, except for fire ants which are primarily nesting outside, PCEs were unable to locate their nest sites (Fig. 2). These results indicate the importance of bait development, which would preclude the necessity of finding the nest in order to treat.

Most customers were calling PCEs for ant control because the ants were perceived as a nuisance (Fig. 3). This is true even for carpenter ants, which are considered to be wood-destroying organisms. There were a few cases of food infestation with ghost and Pharaoh ants, and several cases of biting and stinging by fire ants (Fig. 3).

TABLE 2. OCCURRENCE OF OCCASIONAL PEST ANTS, THE LOCATION WHERE THEY WERE COLLECTED AND THE COUNTIES WHERE THEY WERE COLLECTED.

Species (Samples)	Collection Location[1] No. Inside	No. Outside	County
Brachymyrmex spp. (8)[2]	5	3	Collier, Hillsborough, Palm Beach, Pinellas, Sarasota
B. musculus (2)	1	1	Duval, Polk
B. obscurior (5)	3	2	Broward, Collier, Lee, Orange
Camponotus spp. (5)[2]	3	2	Palm Beach, Pinellas, Seminole, St. Lucie
C. castaneus (10)	6	9	Brevard, Flagler, Hernando, Hillsborough, Polk, Volusia
C. decipiens (2)	2	2	Hillsborough, Volusia
C. planatus (3)	2	3	Broward, Indian River, Lee
C. socius (1)	1	0	Bay
Colobopsis impressus (2)	-	1	Charlotte, Polk
Crematogaster ashmeadi (9)	6	3	Collier, Hillsborough, Palm Beach, Pinellas, Polk
Dorymyrmex bureni (14)	2	11	Bay, Charlotte, Collier, Escambia, Hernando, Jackson, Lee, Orange, Pasco, Pinellas, Seminole, Volusia
Linepithema humile (8)	3	6	Bay, Escambia, Hillsborough, Okaloosa, Pinellas, Walton
Monomorium floricola (8)	5	4	Brevard, Charlotte, Collier, Dade, Lee, Palm Beach, Pinellas
M. trageri (2)	2	1	Jackson, Volusia
Odontomachus ruginodis (7)	3	7	Broward, Charlotte, Collier, Orange, Palm Beach, Pinellas
Paratrechina faisonensis (1)	1	1	Okaloosa
P. pubens (1)	1	1	Palm Beach
Pheidole spp. (6)[2]	4	3	Broward, Collier, Palm Beach, Polk, Volusia
P. dentata (4)	1	-	Lee, Palm Beach
P. fallax obscurithorax (2)	1	2	Escambia
P. floridana (2)	1	1	Collier, Orange
P. metallescens (1)	0	1	Hillsborough
P. moerens (5)	4	2	Lake, Pinellas, Seminole, Volusia
P. morrisi (3)	2	2	Bay, Citrus, Volusia
Platythyrea punctata (1)	1	1	St. Lucie

[1]Total may not add up to no. of samples because some samples were found both inside and outside or in the case of (-) were not recorded on the survey questionaire.

[2]Unidentified male ants.

TABLE 2. OCCURRENCE OF OCCASIONAL PEST ANTS, THE LOCATION WHERE THEY WERE COLLECTED AND THE COUNTIES WHERE THEY WERE COLLECTED.

Species (Samples)	Collection Location[1] No. Inside	No. Outside	County
Pogonomyrmex badius (8)	1	8	Bay, Escambia, Pinellas, Walton
Pseudomyrmex mexicanus (8)	5	4	Broward, Collier, Hillsborough, Lee, Orange, Polk, Sarasota
P. cubaensis (1)	0	1	Palm Beach
Solenopsis geminata (2)	0	2	Collier, Lake
Technomyrmex albipes (8)	5	6	Dade, Palm Beach
Tetramorium simillimum (2)	-	-	Palm Beach
Wasmannia auropunctata (2)	0	1	Broward, Collier

[1]Total may not add up to no. of samples because some samples were found both inside and outside or in the case of (-) were not recorded on the survey questionaire.
[2]Unidentified male ants.

There were enough carpenter ant alates collected that a slight seasonal difference in swarming is suggested between *C. abdominalis* and *C. tortuganus*, with the former being more evident in late summer and the latter in spring and early summer.

Responses to the last part of the questionaire on treatment strategy indicate that for ant control PCEs are relying heavily on sprays and dusts (Fig. 4). For Pharaoh and ghost ants there is a significant use of baits, mainly due to the availability of several effective baits for these ants. The lack of baits for the other common species again indicates the necessity for their development, due to their ease of application, efficacy, reduced pesticide use and the consequent environmental safety.

In the following section, the other occasional pest ants (Table 2) are listed in alphabetical order with a brief description of the results from this survey and previous findings.

Brachymyrmex spp.: Two species were collected, *B. obscurior* Forel and *B. musculus* Forel. Alates were collected in nearly half (47%) of the 15 samples, and the alates presence was sometimes the pest problem. For instance alates by the hundreds in screened swimming pools occurred twice. And for one of the authors, JRM, alates are a daily problem in his swimming pool every summer.

Camponotus spp.: Four species, *C. castaneus* (Latreille), *C. decipiens* Emery, *C. planatus* Roger and *C. socius* Roger were collected as occasional pests, in addition to the more common *C. abdominalis* and *C. tortuganus*. *C. castaneus* was the third most frequent carpenter ant (10 samples) with their alates being the typical pest caste found indoors (90% of samples were alates).

Crematogaster ashmeadi Mayr: Of the 6 (Johnson 1988) or 7 (Deyrup et al. 1989) known Florida species, this was the only *Crematogaster* collected as a pest. In several instances nests were located within buildings. Three of the eight samples consisted of alates. In the sample from Hillsborough Co., the bicolored morph (Johnson 1988) was collected.

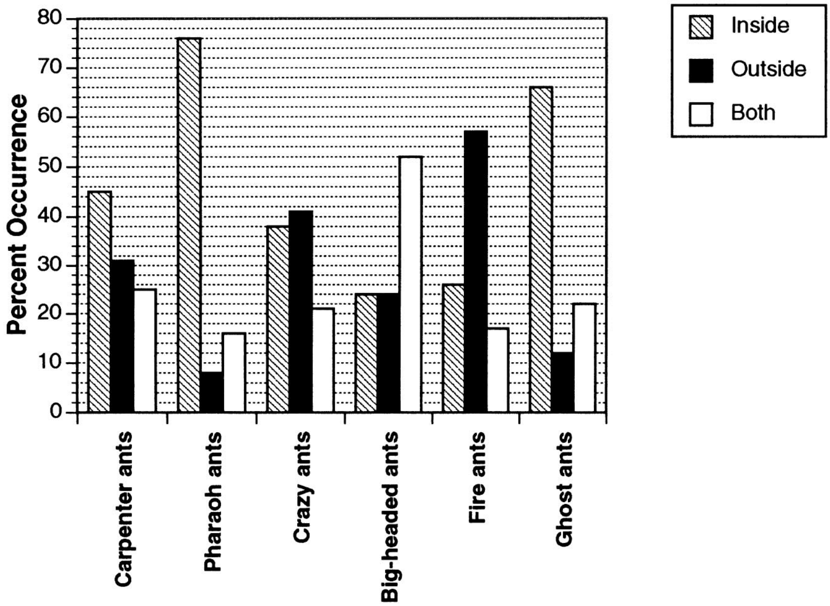

Fig. 1. Frequency of ants located by PCEs inspecting inside, outside, or both inside and outside of structures. Carpenter ants include all *Camponotus* species and crazy ants include *P. longicornis* and *P. bourbonica*.

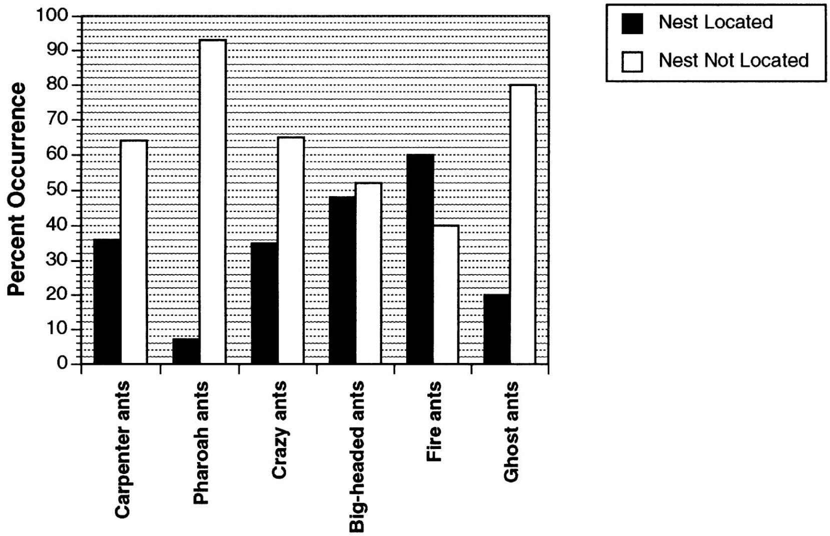

Fig. 2. Frequency of ant nests which were located or not located by PCEs doing inspections. Carpenter ants include all *Camponotus* species and crazy ants include *P. longicornis* and *P. bourbonica*.

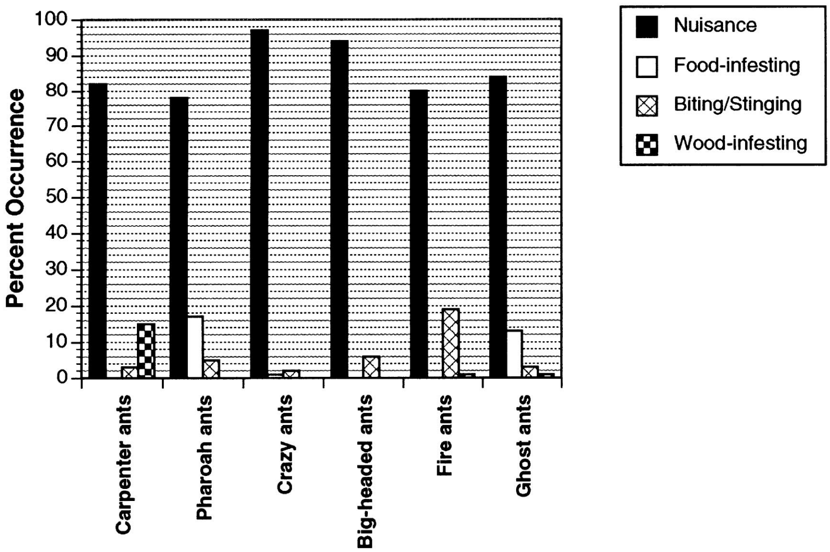

Fig. 3. Frequency of different complaints reported to PCEs from customers with pest ants. Carpenter ants include all *Camponotus* species and crazy ants include *P. longicornis* and *P. bourbonica*.

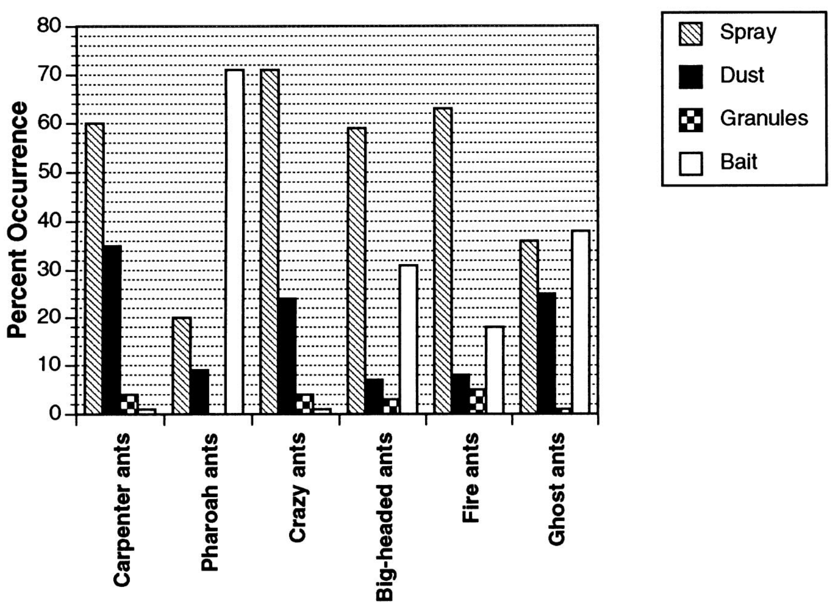

Fig. 4. Frequency of different treatments used by PCEs for control of pest ants. Carpenter ants include all *Camponotus* species and crazy ants include *P. longicornis* and *P. bourbonica*.

Dorymyrmex bureni (Trager): This ant is sometimes considered a pest by homeowners, probably due to the conspicuous nest craters it creates in sandy lawns, although 2 of the 12 samples were reported from indoors.

Linepithema humile (Mayr): The Argentine ant is widespread, but highly localized in Florida (Deyrup 1991a), possibly due to its displacement by S. invicta (Porter et al. 1988). In some areas it is a significant pest invading buildings in large numbers.

Monomorium floricola (Jerdon): Smith (1965) stated that it is unknown whether this ant nests inside homes. Five of the 7 samples in this survey were collected inside structures.

Odontomachus ruginodus Wheeler: Five of the 7 samples were collected from the outside of structures. The two collections inside were associated with door and window frames. Nests of this ant are often seen in expansion joints in concrete around malls and, in this survey, a sample was collected from a sidewalk and a driveway.

Paratrechina pubens (Forel): A home in Boca Raton had numerous ants both inside and outside. The following observations were made prior to the survey by one of the authors (JRM). In 1990, hundreds of these ants were found on the second floor of a large Miami hospital (approximately 712 beds) and around a commercial building near Homestead. Previously they have been collected within USDA greenhouses in Washington D.C. (Trager 1984).

Pheidole spp.: In addition to *P. megacephala*, 6 species of *Pheidole* were collected: *P. dentata* Mayr, *P. fallax obscurithorax* Santschi, *P. moerens* Wheeler, *P. floridana* Emery, *P. metallescens* Emery and *P. morrisi* Forel. None of these six were very numerous indoors or presented any difficulty with control. Smith (1965) includes *P. dentata* and *P. floridana* as structural ant pests.

Platythyrea punctata (F. Smith): One sample was collected indoors where they had entered a home and stung the occupants.

Pogonomyrmex badius (Latreille): This ant was collected 8 times. Seven of the samples were collected outside, where its nests are large and conspicuous.

Pseudomyrmex spp.: Two species were found as pests, *P. mexicanus* (Roger) and *P. cubaensis* (Forel). Of the 5 inside pest collections of *P. mexicanus*, 3 were from nests associated with doors and 2 were from the kitchen. Only a few workers were found. The one sample of *P. cubaensis* was taken from a patio, following a homeowner's complaint about allergic reaction to stings.

Solenopsis geminata (Fabricius): Only 2 samples were collected in this survey and this might reflect this ant's absence from coastal areas and preference for coarse, excessively drained soil (Deyrup 1991a).

Technomyrmex albipes (F. Smith): Perhaps Florida's newest exotic pest ant, it was collected from 8 homes in Palm Beach and Dade Co.. Deyrup (1991b) reviewed the status of this ant in Florida, mentioning 1986 and 1990 collections from Dade Co. Two of the 8 infested homes had large multiple invasions of worker ants for several years, with colonies established in exterior walls and attics. Alates inside two of the homes were also a nuisance. Based on reports of Yamauchi et. al (1991) of huge polydomous colonies with several million workers and its house pest status in South Africa (Prins et al. 1990), it may have tremendous potential as a widespread pest ant in Florida. It is also known to enter switches of relays (Little 1984) and were responsible for disabling a light switch in one Palm Beach Co. home.

Tetramorium simillimum (F. Smith): Both samples of this ant from Palm Beach Co. were alates causing a nuisance problem.

Wasmannia auropunctata (Roger): Only two samples were collected. The low incidence of this ant is surprising given its widespread occurrence in 15 Florida counties (Deyrup et al. 1989) and common occurrence around structures in south Florida (JRM unpublished). Ulloa-Chacon & Cherix (1990) classify it as both an agricultural and structural pest.

This study presents a snapshot of Florida pest ants in 1993. Many of the exotic pest ants in Florida are well known invaders (Deyrup 1991a; Porter et al. 1988) including *S. invicta*, *P. megacephala*, *L. humile* and *W. auropunctata*. Other exotic common and occasional Florida pest ants such as *T. melanocephalum* and *T. albipes* appear to be extending their range.

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We thank the pest control employees of Terminix International Co. L.P. for their careful and diligent collection of ant specimens and completion of survey questionnaires. We also thank Mark Deyrup, Archbold Biological Station, Lake Placid, Florida; Stefan P. Cover, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts; Phil Ward, University of California, Davis; and Roy Snelling, Los Angeles County Museum for help with identification.

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INTRACOLONY MORPHOMETRIC VARIATION AND LABRAL SHAPE IN FLORIDA *RETICULITERMES* (ISOPTERA: RHINOTERMITIDAE) SOLDIERS: SIGNIFICANCE FOR IDENTIFICATION

NIKLAUS C. HOSTETTLER[1], DONALD W. HALL[1], AND RUDOLF H. SCHEFFRAHN[2]
[1]Department of Entomology & Nematology, Bldg. 970 - Hull Road
University of Florida, Gainesville, FL 32611-0620

[2]Fort Lauderdale Research and Education Center, 205 College Avenue,
Fort Lauderdale, FL 33314-7700

ABSTRACT

Measurements of pronotal width, broadest gular width, and labral length of *Reticulitermes* soldiers collected in San Felasco State Preserve, Florida, showed considerable intracolony variation and interspecific overlap. The termites collected did not differ in size from termites collected state wide. The reported 0.81 mm pronotal width threshold failed to separate soldiers of *R. flavipes* from *R. virginicus*. An average pronotal width measurement (n<5) ≥ 0.90 mm denotes *R. flavipes*, ≤ 0.70 mm *R. hageni*, and 0.71 - 0.80 mm *R. virginicus*. A threshold at 0.85 mm (n>5) separates *R. flavipes* from *R. virginicus*. A new character, labral shape, was found to be very reliable for separating the three species.

Key Words: Pronotal width, measurements, gula, subterranean termites,

RESUMEN

Las medidas del ancho pronotal, máximo ancho gular y longitud del labrum de soldados de *Reticulitermes*, celectados en la Reserva Estatal de San Felasco en Florida, mostraron considerable variación y sobreposición interspecífica. Las termitas colectadas no presentaron diferencia en tamaño de aquellas celectadas en el resto del estado. La medida del ancho pronotal registrado de 0.81 mm como limite para separar los soldados de *R. flavipes* de *R. virginicus,* no fue de utilidad. El promedio de las medidas del ancho pronotal (n>5) ≥ 0.9 mm hace referencia a *R. flavipes*, ≤ 0.7 mm a *R. hageni*, 0.71 - 0.80 mm a *R. virginicus*, y un límite de 0.85 mm (n>5) separa *R. flavipes* de *R. virginicus*. Un nuevo carácter encontrado, la forma del labrum, fué muy confiable para separar las 3 especies.

Three species of subterranean termites in the genus *Reticulitermes*, *R. flavipes* (Kollar), *R. virginicus* (Banks) and *R. hageni* Banks, occur in Florida (Miller 1949, Scheffrahn et al. 1988). These species are prominent biotic elements in the confluence of wood and soil in Florida and the southeastern United States, and are of considerable economic importance (Scheffrahn et al. 1988). Confirmatory species identification has been based on characters of the winged imago (alate) which, unfortunately, is a seasonal caste and usually not collected simultaneously with soldiers and workers. The soldiers, present in the colony throughout the year, possess more subtle and, in some cases, rather variable characters making their correct identification more difficult than alates.

In their key to *Reticulitermes* soldiers, Banks & Snyder (1920) differentiated the three species occurring in Florida by size: the larger being *R. flavipes*, the smaller either *R. virginicus* or *R. hageni*. Banks (1946), Emerson & Miller (1943), and Miller (1949) used soldier pronotal width to separate *R. flavipes* (0.81-1.10 mm) from *R. virginicus* and *R. hageni* (0.67-0.81 mm). Soldiers of the latter two species were separated by these authors using the shape of the gula (postmentum) and mandibles. They reported that the gula of *R. virginicus* had more abrupt inward curvatures of its lateral margins than those of *R. hageni* and that the degree of curvature of the mandibular points was greater in *R. virginicus* than in *R. hageni*. In his key, Snyder (1954) used the total length of soldiers to separate *R. flavipes* (6.7 mm) from *R. virginicus* (4.5 - 5.0 mm) and he specified the gular characters mentioned above to separate *R. virginicus* from *R. hageni*.

In his attempt to identify diagnostic characters for soldiers of eastern U.S. species of *Reticulitermes*, Banks (1946) compared 13 morphometric measurements taken from three or more soldiers per colony (number of colonies not specified) of each species, and found overlap for all three species in 11 of the measurements. The two remaining measurements, head length with mandibles and posterior head width, yielded overlap among the largest *R. hageni* and the smallest *R. virginicus* and among the largest *R. virginicus* and the smallest *R. flavipes*.

Based on specimens collected throughout Florida, we found that the three species differ in size, with soldiers of *R. flavipes* being the largest and those of *R. hageni* the smallest. In their key to termite soldiers of Florida, Scheffrahn & Su (1994) use *R. flavipes* pronotum width (> 0.90 mm) and head length (≥ 2.8 mm) to separate this species from *R. virginicus* (pronotum width < 0.85 mm and head length ≤ 2.7 mm). Soldiers of *R. hageni* could be separated fairly reliably from those of the other two species by the shape and degree of curvature of the mandibles and its diminutive pronotal width (≤ 0.70 mm).

In previous studies of *Reticulitermes* soldiers, intracolony variation was not explored as an additional source of morphometric variation within a species. Such measurements would be useful in confirming the reliability of morphometric characters. Intracolony measurements (n=2-3) taken of slide-mounted pronota, gula, and labra revealed colony specific variation which contributed to character overlap. Interspecific overlap was found in all measurements except for the broadest gular width and labral length. Proportions calculated from our measurements were inconclusive for species separation.

This paper reports on the intracolony variation of the soldiers of the three *Reticulitermes* species recognized in Florida for pronotal width, broadest gular width, and labral length, and assesses the limitations of using pronotal width to separate *R. virginicus* from *R. flavipes*. We also describe the use of labral shape as an additional character for differentiating soldiers of the three *Reticulitermes* species found in Florida.

MATERIALS AND METHODS

A total of 67 *Reticulitermes* colonies (31 *R. flavipes*, 26 *R. virginicus*, 9 *R. hageni* samples, and one unknown) from San Felasco State Preserve, Alachua Co., Florida, were sampled by collecting foraging groups (i.e. soldiers, workers, and, if present, alates) associated with each colony. Alates were used to identify ten *R. flavipes*, four *R. virginicus*, and one *R. hageni* sample. The remainder were grouped by pronotal width and identified by the labral character described herein. Voucher specimens from each colony were preserved by killing in hot water, fixing overnight in 2.5% glutaraldehyde with a trace of Triton X or Watsol (wetting agents) in cacodylate buffer

(0.1M, pH 7.2), rinsing with water, and storing in 75% ethanol with 5% glycerol. The labrum, gula, and pronotum from 2-3 soldiers of each colony were mounted on microscope slides under cover slips in Hoyer's medium (Kranz 1987). Preliminary measurements of pronotal width were taken of preserved soldiers (n<=10) using a stereomicroscope at 50x equipped with an ocular micrometer. Later measurements also were taken of pronotal width and length, labral width and length, and gular widths (broadest and smallest) and length of the slide mounts using a compound microscope at 100x equipped with an ocular micrometer.

Based on the pronotal measurements above, ten colonies were selected to assess intracolony measurement variation and interspecific measurement overlap for the *Reticulitermes* populations at San Felasco. The *R. hageni* colonies consisted of typically-sized and large-sized soldiers, 89 and 49 were measured respectively; the *R. virginicus* colonies consisted of small-sized and typically-sized soldiers, 88 and 80 were measured respectively; and the *R. flavipes* colonies of small-sized and typically-sized soldier, 87 and 80 were measured respectively. Because no *R. virginicus* colonies consisting of large-sized soldiers with a sufficiently large number of soldiers were available, additional four sample sets of 12-13 soldiers from colonies consisting of large-sized *R. virginicus* soldiers were prepared. A greater representation of large-sized *R. virginicus* soldiers was sought because these were most likely to be confused with *R. flavipes*. The labra, gula, and pronota of these soldiers were dissected and mounted on microscope slides under cover slips in Hoyer's medium. Measurements were made of pronotal width, broadest gular width, and labral length using a compound microscope at 100X and an ocular micrometer.

Soldier pronotal width measurements in the five colonies having ≥ 80 soldiers were used to estimate a minimum sample size to calculate a reliable, species-specific measurement. Assuming a random sample of the sequentially obtained measurements, a running mean and the deviation of this mean from the overall mean was calculated.

To compare the 67 San Felasco samples with those of *Reticulitermes* state-wide, the pronotal width of soldiers from 29 colony samples (13 *R. flavipes*, 13 *R. virginicus*, and 3 *R. hageni*) from the Florida Counties of Hillsborough, Broward, Washington, Pinellas, Brevard, Palm Beach, Alachua, Okeechobee, Volusia, Orange, and Dade were measured. Alates were used for primary identification and either one or two soldiers from each colony sample was measured. These samples were from the termite collection at the University of Florida, Ft. Lauderdale R.E.C.

Soldiers and workers from alate-identified San Felasco colonies were examined for external morphological differences using a Hitachi scanning electron microscope at 15kV. The specimens were dehydrated through an ethanol series, transferred to hexamethyldisilazane (Nation 1983), mounted on SEM stubs, and sputter-coated with gold.

RESULTS AND DISCUSSION

Measurements (mm) of pronotal width, gular width, and labral length of soldiers from the ten San Felasco *Reticulitermes* colonies are presented in Fig. 1. Because we mounted the pronota on slides which flattened these weakly convex structures, our measurements are slightly larger than those of published keys, but should be more accurate for relative comparisons. The colonies selected consisted of both larger and smaller soldiers within the same species, probably determined by intrinsic genetic factors or by external factors such as nutritional status and colony age. No overlap in pronotal width between *R. hageni* and *R. virginicus* was observed. However, there was significant overlap in broadest gular width, labral length, and pronotal width among

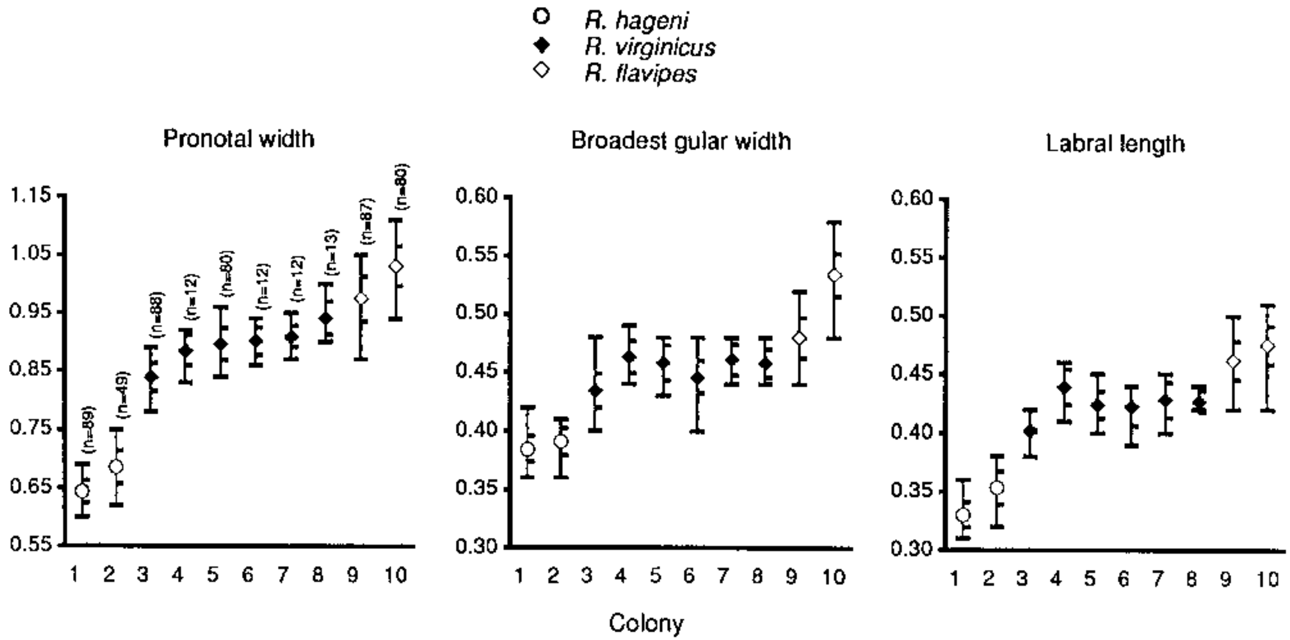

Fig. 1. Average (+-SD), minimum, and maximum measurements (mm) of soldiers from 10 *Reticulitermes* spp. colonies from San Felasco State Preserve. Measurements from slide mounted pronota, labra, and gula; sample size given in figure.

R. virginicus and *R. flavipes* soldiers. In fact, the mean pronotal width of one of the *R. virginicus* colonies (n = 13) falls within one standard deviation of the mean for one of the colonies (n = 87) of *R. flavipes*. Furthermore, the ranges of all six colonies of *R. virginicus* overlap the range of one (n = 87) of the *R. flavipes* colonies for all three measurements.

The labral length and broadest gular width were selected because no intracolony specific overlaps were previously encountered. However, the data in Fig. 1 show that these measurements are of little value for separating the *R. virginicus* and *R. flavipes* colonies and demonstrate the inherent danger of making inferences about size using measurements obtained from only a few individuals.

Although Fig. 1 shows pronotal width overlap between *R. virginicus* and *R. flavipes*, the means (n = 10) taken of whole soldiers showed three distinct groups each corresponding to a species (Table 1). While these ranges may not be representative of all populations in Florida, the San Felasco measurements do not differ from those obtained from termites collected throughout Florida (Table 2). Even though some pronotal width measurements do overlap, it does show that with some limitation, this measurement is useful for species separation.

In order to use the pronotal width mean value with some degree of confidence, a certain minimum colony sample size is needed. The frequency distributions of the data used for Fig. 1 indicated that the measurements were normally distributed. As the sample size increases, an extreme value has less effect on the mean. Fig. 2 shows the deviation of a running mean calculated from the overall mean, calculated in exact order as the measurements were obtained to assure a random sampling. With a sample size of n=10, the deviation is within 0.020 mm, 0.014 mm for *R. hageni*, 0.012 mm for *R. virginicus* and 0.018 mm for *R. flavipes*. This result, and the standard deviations in Fig. 1, indicate that a mean obtained from less than 5 specimens should be used with caution. Measuring more than ten specimens probably will not yield a much more accurate mean.

A fairly reliable characteristic that we found to be useful in separating these species is the shape of the labrum viewed on slide mounts (Fig. 3). The labrum of *R. hageni* is elongated with the ratio of length beyond the anteclypeus (i.e. sclerotized area) to greatest width > 1.2. The lateral margins of the distal 3/4 of the labrum are straight or slightly concave and converge at a uniformly rounded tip (Figs. 3a and 4a). The labrum of *R. virginicus* is diamond-shaped with angular lateral margins converging into an obtuse point. The ratio of length:width is < 1.2. If the two lines forming the anterior margin were extended they would intersect beyond the tip (Figs. 3b and 4b).

TABLE 1. RANGE OF COLONY PRONOTAL WIDTH MEANS (MM) OF *RETICULITERMES* SOLDIERS[A].

Species	Smallest	Largest
R. flavipes	0.88	1.03
R. virginicus	0.73	0.83
R. hageni	0.58	0.67
Unknown	0.80	

[a]Whole soldiers measured.

TABLE 2. PRONOTAL WIDTH MEASUREMENTS[a] (MM) OF INDIVIDUAL *RETICULITERMES* SOLDIERS.

	San Felasco State Preserve				Florida			
Species	N[b]	Colonies	Range	Average±SD	N[c]	Colonies	Range	Average±SD
R. flavipes	298	31	0.81 - 1.11	0.95 ± 0.051	23	13	0.86 - 1.13	0.95 ± 0.16
R. virginicus	250	26	0.71 - 0.87	0.79 ± 0.030	24	13	0.70 - 0.84	0.78 ± 0.10
R. hageni	79	9	0.55 - 0.71	0.62 ± 0.036	5	3	0.65 - 0.71	0.68 ± 0.08
Unknown	9	1	0.80 - 0.81	0.80 ± 0.010				
Total	636	67			52	29		

[a]Whole soldiers measured.
[b]Maximum 10 soldiers per colony.
[c]Maximum 2 soldiers per colony.

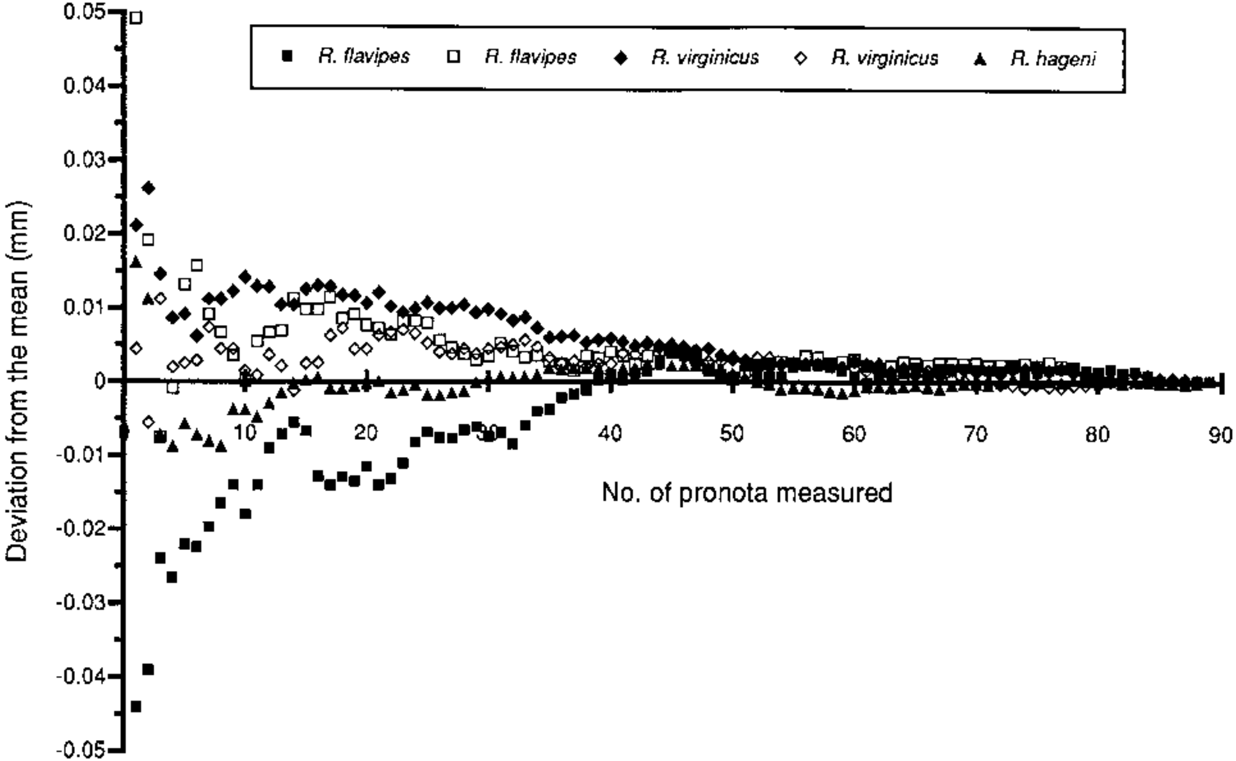

Fig. 2. Deviation of the running pronotal width mean from the overall mean (n = 80-89) of soldiers from five *Reticulitermes* spp. colonies.

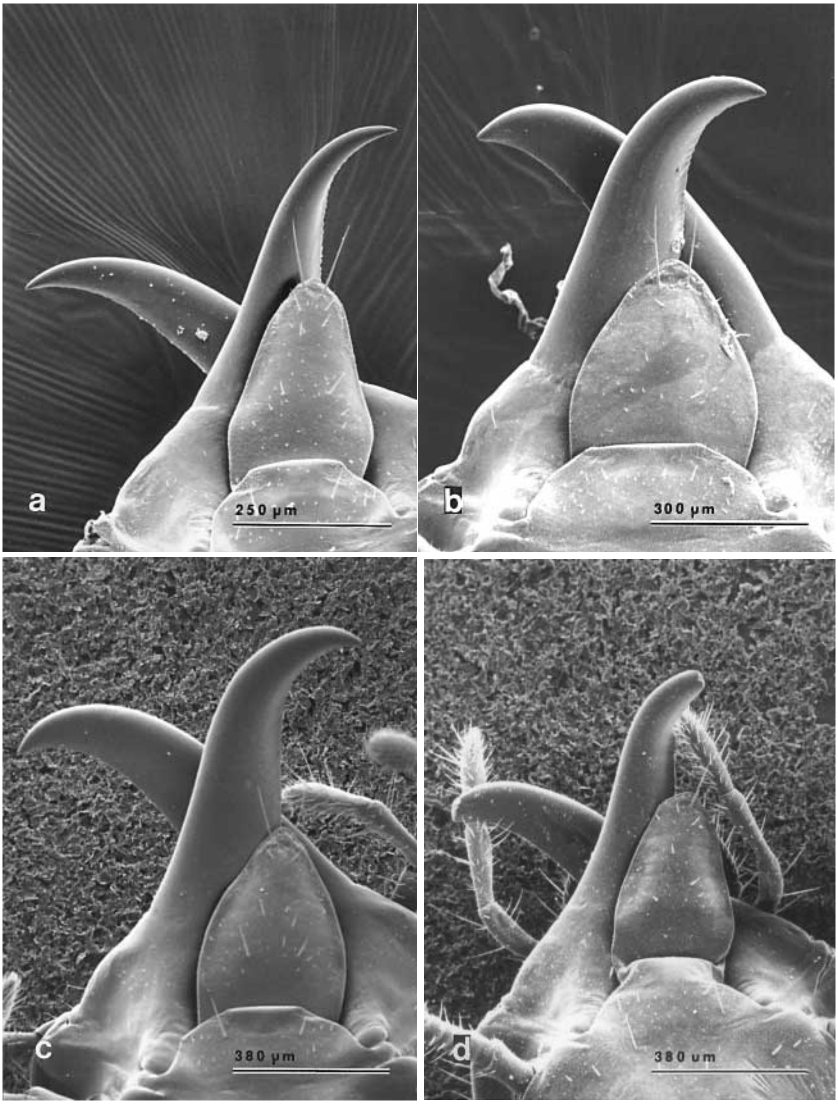

Fig. 3. Electron microphotographs of *Reticulitermes* spp. soldier labra: a) *R. hageni*, b) *R. virginicus*, c) *R. flavipes*, d) *Reticulitermes* sp. unknown.

The labrum of *R. flavipes* forms an outline resembling a flatiron with a frontal projection. The lateral margins are evenly convex from their bases to their distal 2/3-3/4 where a more or less distinct concavity precedes a rounded or an acutely pointed triangular tip. If the two lines forming the anterior lateral margins were extended they would intersect short of the tip (Figs. 3c and 4c).

Labral proportions are relatively constant within a colony for *R. hageni* but variable for *R. virginicus* and *R. flavipes*. The sides of *Reticulitermes* labra are rather

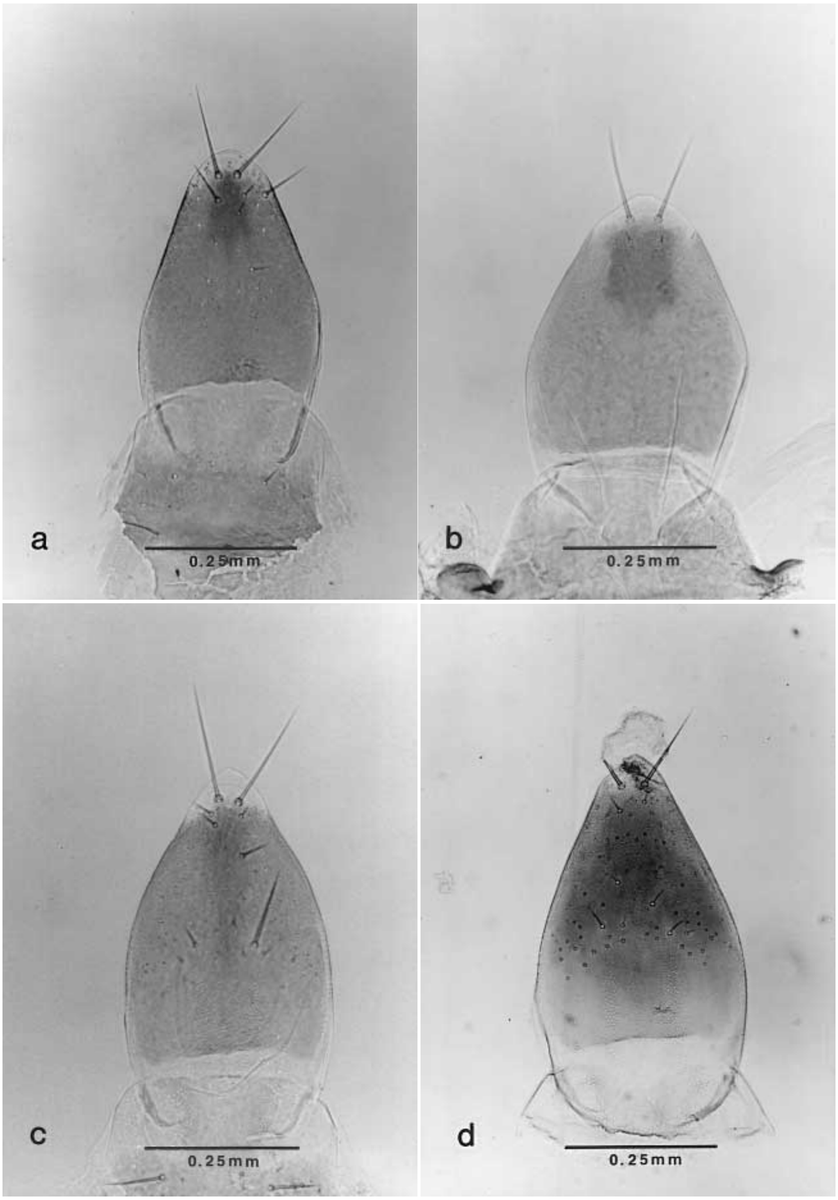

Fig. 4. Light microphotographs of microscope slide-mounted *Reticulitermes* spp. soldier labra: a) *R. hageni*, b) *R. virginicus*, c) *R. flavipes*, d) *Reticulitermes* sp., 100x.

asymmetrical and the characters described above are often more apparent on one side. A mounted labrum usually lies slightly to one side amplifying its apparent asymmetry. The tip of the labrum is subject to wear and tear and therefore sometimes dam-

TABLE 3. NUMBER OF SLIDE MOUNTS NEEDED FOR POSITIVE IDENTIFICATION.

		No. (cumm.%) of Colonies Identified From:			
	No. Colonies	1 Mount	2 Mounts	3 Mounts	Tentative ID
R. flavipes	31	18 (58)	11 (94)	2 (100)	-
R. virginicus	26	20 (76)	5 (96)		1
R. hageni	9	9 (100)	-	-	-
Total	66	47 (71)	16 (95)	2 (98)	1

aged. Aberrant individuals can occur in a colony but most conform to the basic characteristics described.

When examining whole soldiers in alcohol using a stereo microscope, it may be difficult to see the labral characteristics, but these helpful rules generally apply: the posterior sides of the labrum of *R. flavipes* are never angular, and the labral tip of *R. virginicus* is never an acute point; the labral tip is always narrow for *R. hageni* and always broad for *R. virginicus*; and the length:broadest width ratio is > 1.2 for *R. hageni* and < 1.2 for *R. virginicus*. It is imperative to position the whole soldier such that the viewing angle is perpendicular to the labrum. Freely detached labra in alcohol viewed at 50x reveal the shape distinctly enough to make an identification most of the time. The shape is usually more evident if the removed labrum is viewed ventral side up. Table 3 shows the frequency of positive identifications of the slide mounted labra for the San Felasco collection. Correct identification frequencies were found not to differ among other *Reticulitermes* collections examined.

Our standard procedure is to make a microscope slide mount of the labrum and the pronotum from two soldiers, and from a third soldier if no confident identification was possible with two (see Table 3). The pronotal width is an easily obtained, very useful reference that has been widely used. Pronotal width reflects the size of soldiers in a colony, and therefore is a strong suggestion of species (Tables 1 and 2). Based on our Florida *Reticulitermes* collections, it is always possible to find an unusually small individual in a colony, but an upper size limit for the species appears to be the norm. Allowing for a slight margin of error, a pronotal width measurement (whole soldier, n<5) larger than 0.90 mm denotes *R. flavipes*, less than 0.70 mm *R. hageni*, and the range of 0.71 - 0.80 mm *R. virginicus*. A treshold at 0.85 mm (n>5) separates *R. flavipes* from *R. virginicus*.

During the study, a single colony with intermediate-sized soldiers which could not be identified was collected from a very dry, 4 ft tall standing stem of *Pinus palustris* Mill. The mandibles were identical to those of *R. virginicus* and *R. flavipes*, but the shape of the labrum was similar to that of *R. hageni* (Fig. 3d & 4d). These characters were consistent among all soldiers.

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EVALUATION OF TSETSE ATTRACTANTS AS BAITS FOR HORSE FLIES AND DEER FLIES (DIPTERA: TABANIDAE) IN LOUISIANA

LANE D. FOIL[1] AND LAWRENCE J. HRIBAR[2]
[1]Department of Entomology, Louisiana Agricultural Experiment Station,
Louisiana State University Agricultural Center,
Baton Rouge, LA 70803

[2]Florida Medical Entomology Laboratory, University of Florida,
Institute of Food and Agricultural Sciences, 200 9th St. SE,
Vero Beach, FL 32962

ABSTRACT

Two experiments were conducted near Washington, Louisiana, to evaluate attraction of Tabanidae to known tsetse attractants. In the first experiment octenol was dispensed from reaction vials and polyethylene sachets, acetone was dispensed from a jar capped with a perforated lid, and a mixture of octenol, 3-*n*-propylphenol, and 4-methylphenol (4:1:8) was dispensed from sachets. Fourteen species or species groups of tabanid flies were attracted equally to octenol, whether dispensed from reaction vials or sachets. There were no differences in numbers of tabanids attracted to 4:1:8 bait and to octenol, whether dispensed from sachets or reaction vials. Acetone was no more attractive than were control traps. In the second experiment, 4:1:8, acetone, 4:1:8 + acetone (1:50), and commercially available pepper sauce (Tabasco[R]) were compared. Nine species or species groups of tabanid flies were collected. The 4:1:8 and 4:1:8 + acetone baits were equally attractive to tabanids, whereas there were no differences among the pepper sauce, acetone, and unbaited controls.

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Key Words: trapping, octenol, acetone, phenols, pepper

RESUMEN

Se condujeron dos experimentos cerca de Washington, Louisiana, para evaluar la atracción de tábanos a cebos conocidos de tsetsé. En el primer experimento el octenol fue dispensada directamente de ampolletas de reacción y de perfumadoras de polietileno (sachets), acetona de un jarro tapado con una tapa perforada, y 4:1:8 (una mezcla de octenol, 3-*n*-polipropilfenol, y 4-metilfenol) de una perfumadora. Se recobraron catorce especies o grupos de especies. Los tábanos fueron atraídos igualmente al octenol cuando se dispensó de las ampolletas de reacción o de los perfumadoras. No se encontró ninguna diferencia en el número de tábanos atraídos a cebos de 4:1:8 o octenol. No se encontró ninguna diferencia entre la acetona o las trampas controles sin cebo. En el segundo experimento, se compararon 4:1:8, acetona, 4:1:8 + acetona (1:50), y salsa picante disponible comercialmente (Tabasco[R]). Se recobraron nueve especies o grupos de especies. Los cebos 4:1:8 y 4:1:8 + acetona fueron igualmente atractivos a los tábanos, pero no se encontró diferencias alguna entre la salsa picante, acetona, y trampas controles sin cebo.

Chemical attractants in traps are used in many parts of the world to attract biting flies. In Africa, traps baited with a mixture of octenol, 3-*n*-propylphenol, and 4-methylphenol in the proportions 4:1:8 are used in tsetse control programs (Vale et al. 1988b). Brady & Griffiths (1993) found that this combination of chemicals, which they called "4:1:8", elicited a response by tsetse similar to that elicited by carbon dioxide, and that acetone elicited a weaker response. French & Kline (1989) reported that octenol was an effective attractant for tabanid flies. We report here a field trial evaluating these tsetse attractants for collecting tabanids in Louisiana.

MATERIALS AND METHODS

Two experiments were conducted at the Thistlethwaite Wildlife Management Area (WMA), near the town of Washington in St. Landry Parish, Louisiana. The study site has been described previously by Leprince et al. (1991). The first experiment was conducted for ten days between 11 June and 25 June 1993 using canopy traps (Hribar et al. 1991) for collecting the horse flies. Four baits were evaluated and dispensed in the following manner: 4:1:8, in polyethylene sachets (Brady & Griffiths 1993); 3 ml octenol, in reaction vials (octenol-R) in the "wick out" position (French & Kline 1989); 100 ml acetone, in a jar with a 6 mm diam hole in the lid; and octenol in a sachet (octenol-S). Release rates for all delivery systems are given by French & Kline (1989) and Phelps & Holloway (1992). Each dispensing device was placed into a 0.9 liter canning jar located at the base of the center pole of the canopy trap. This method was used to avoid contaminating the cloth traps with chemicals. Each bait was used in two traps per day, for a subtotal of eight baited traps. Two unbaited traps served as controls, making a total of ten traps per day. Baits were rotated among traps daily so that every bait was used at every trap site. Baits were assigned to traps according to the SAS PLAN procedure (SAS Institute 1985). To avoid interference between baits, no less than 50 m separated any two traps (Inoue et al. 1973).

A second experiment, to evaluate phenols in the absence of undiluted octenol, was conducted over a 5-day period from 29 June to 7 July 1993. Four baits were evaluated:

acetone, 4:1:8 in sachets, 4:1:8 in acetone (1:50), and a commercially available pepper sauce (Tabasco[R]). Each bait was used in two traps per day, along with two unbaited control traps, for a total of ten traps per day. Acetone and 4:1:8 were released in the same manner as in the first experiment. The combination of 4:1:8 + acetone was released in the same manner as was acetone in the first experiment. Tabasco[R] sauce was placed into 5-ml reaction vials without lids. The pepper sauce was compared to previously described tsetse attractants as a control for enhanced trap efficacy due to irritation or insult of olfactory sensilla. As in the first experiment, each bait dispensing device was placed into a 0.9 liter canning jar which was then placed at the base of the center pole of the canopy traps. Assignment of baits to traps and placement of traps were accomplished in the same manner as in the first experiment.

Tabanid flies were sorted to species with the key of Tidwell (1973). Due to the difficulty of separating *Tabanus lineola* F. from *T. subsimilis* Bellardi, these species were identified as "*T. lineola* complex". Similarly, deer flies were not identified to species, although *Chrysops cursim* Whitney, *C. pudicus* Osten Sacken, and *C. univittatus* Macquart are known to occur at the WMA (Hribar & Foil 1994). Data were transformed as X' = ln(X+1) (Zar 1984) and analyzed by the SAS ANOVA procedure and the Ryan-Einot-Gabriel-Welsch multiple range test (SAS Institute 1985). Results were backtransformed as the antilogarithm minus 1 for presentation.

RESULTS

A total of 7,901 adult female tabanid flies was collected in the first experiment. *Tabanus fuscicostatus* Hine comprised 80.4% of the flies collected. Other species collected, in descending order of abundance, were: *Chrysops* spp. (6.3%), *T. lineola* complex (3.6%), *T. americanus* Forster (3.1%), *T. proximus* Walker (2.3%), *T. pallidescens* Philip (2.0%), and *T. limbatinevris* Macquart (1.7%). *Chlorotabanus crepuscularis* (Bequaert), *Leucotabanus annulatus* (Say), *T. equalis* Hine, *T. atratus* F., *T. molestus* Say, *T. stygius* Say, and *T. wilsoni* Pechuman each comprised less than 1% of the total catch. Analysis of variance revealed differences in numbers of flies caught in traps provided with different baits ($F = 4.26$; df = 4, 50; $P < 0.0048$) (Table 1). There was no site effect ($F = 1.17$; df = 9, 50; $P > 0.3324$), and no significant site × bait interaction ($F = 1.08$; df = 36, 50; $P > 0.3925$). No statistical differences in numbers of flies collected were observed among octenol (R), octenol (S), and 4:1:8. Acetone was no more attractive to tabanids than were unbaited control traps.

TABLE 1. COLLECTION OF ADULT FEMALE TABANIDAE IN CANOPY TRAPS BAITED WITH OCTENOL (R = REACTION VIAL, S = SACHET RELEASE SYSTEM), PHENOLS, OR ACETONE.

Bait	Flies per Trap per Day[1]
Octenol-R	80.859 ± 20.017a
Octenol-S	76.556 ± 15.503ab
4:1:8	69.176 ± 11.043abc
Acetone	43.791 ± 10.232bc
Control	39.165 ± 7.218c

[1]Means ± S.E. followed by the same letter are not significantly different according to the Ryan-Einot-Gabriel-Welsch multiple range test on ln(x+1) transformed data. Backtransformed means are presented.

TABLE 2. COLLECTION OF ADULT FEMALE TABANIDAE IN CANOPY TRAPS BAITED WITH PHENOLS, ACETONE, AND A COMMERCIAL PEPPER SAUCE.

Bait	Flies per Trap per Day[1]
4:1:8	10.145 ± 1.329a
4:1:8 + acetone	8.699 ± 4.623a
Tabasco[R]	3.623 ± 0.683b
Acetone	3.500 ± 0.722b
Control	2.662 ± 0.777b

[1]Means ± S.E. followed by the same letter are not significantly different according to the Ryan-Einot-Gabriel-Welsch multiple range test on ln(x+1) transformed data. Backtransformed means are presented.

A total of 356 flies was collected in the second experiment. Most of these were *T. fuscicostatus* (45.2%) and *T. proximus* (25.6%). The remaining flies were *T. limbatinevris* (8.2%), *Chrysops* spp. (7.9%), *T. americanus* (5.9%), *T. lineola* complex (3.9%), *T. pallidescens* (2.3%), *L. annulatus* (0.8%), and *T. wilsoni* (0.3%). Analysis of variance revealed differences in numbers of flies captured per trap per day among baits ($F = 6.03$; $df = 4, 45$; $P < 0.0006$) (Table 2). The 4:1:8 mixture, whether in combination with acetone or not, was more attractive to tabanids than was acetone, Tabasco[R], or control traps.

DISCUSSION

Acetone, octenol, and phenols all apparently stimulate upwind flight by tsetse (Paynter & Brady 1993). The combination of octenol and phenols appears to be a flight stimulant for tsetse, whereas acetone may be more involved in eliciting visual responses to host silhouettes (Brady & Griffiths 1993).

Phenols serve two functions when attracting tsetse; they attract flies from a distance and increase trap-entering activity (Vale et al. 1988a). Phenols are the attractive component in buffalo urine (Hassanali et al. 1986), whereas octenol is found in the breath of oxen (Hall et al. 1984). Octenol may alert host-seeking female tabanids to the presence of a nearby host. Phenols, found in host urine, may indicate only that a host has been in the area recently, and may not necessarily still be available for a blood meal. The use of the 4:1:8 mixture did not permit separation of effects of octenol and phenols on tabanids. Phelps & Holloway (1992) found that 4-methylphenol was the more strongly attractive phenol, whereas 3-*n*-propylphenol was only weakly attractive to tabanids, and relative to 4-methylphenol, 3-*n*-propylphenol gave no significant increase in numbers of tabanids collected.

The similar response of tabanids in Louisiana to a 1:50 dilution of 4:1:8 in acetone and to undiluted 4:1:8 is consistent with reports of Phelps & Holloway (1992), who described similar results for *Atylotus agrestis* Wiedemann, *Haematopota nocens* Austen, *T. pallulus* Austen, and *T. unilineatus* Loew in Zimbabwe. The phenol mixture obviously is attractive to tabanids even in low concentrations. Dilution of 4:1:8 with acetone does not affect the attractiveness of 4:1:8 to tabanids, even at dilutions of 1:200 (Phelps & Holloway 1992).

The primary difference in numbers of flies collected in the two experiments is explainable in part to the flight period of most species of horse flies, which in southern Louisiana is highest in June (Leprince et al. 1991). This report of equivalent catch by traps baited with octenol released via reaction vial or polyethylene sachet should allow a transition to newer release devices which are much more user friendly and can be manipulated to influence release rates. The interaction of attractants for horse flies undoubtedly will provide many opportunities for study.

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DISCOVERY OF THE MALE OF *AGENIASPIS CITRICOLA* (HYMENOPTERA: ENCYRTIDAE), PARASITOID OF THE CITRUS LEAFMINER *PHYLLOCNISTIS CITRELLA* (LEPIDOPTERA: GRACILLARIIDAE)

GREGORY A. EVANS
Entomology and Nematology Department
University of Florida
Gainesville, FL 32611-0620

ABSTRACT

The male of *Ageniaspis citricola* Logvinoskaya, reared from the citrus leafminer, *Phyllocnistis citrella* Stainton, is described and figured.

Key Words: *Ageniaspis*, citrus leafminer, *Phyllocnistis*, citrus.

RESUMEN

Se describe e ilustra el macho de *Ageniaspis citricola* Logvinoskaya, criado del minador de la hoja de los cítricos, *Phyllocnistis citrella* Stainton.

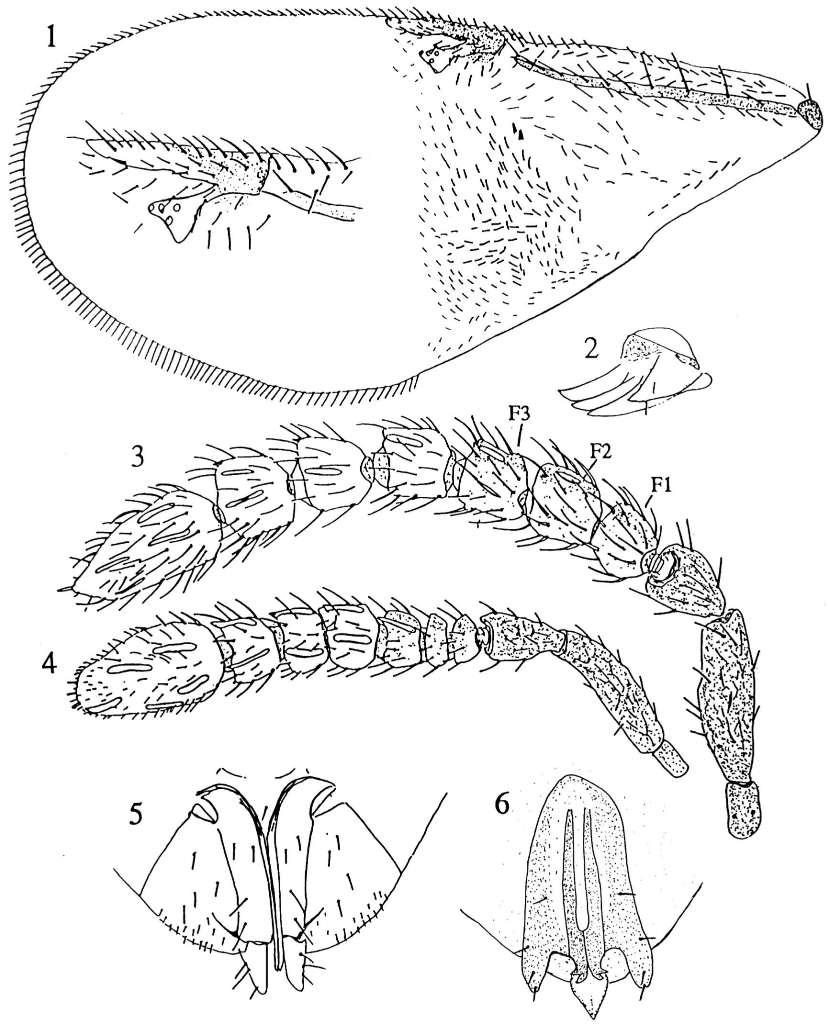
The citrus leafminer, *Phyllocnistis citrella* Stainton invaded Florida citrus in May of 1993 (Knapp et al. 1993). This pest species was described from India in 1856 and was reported for the first time in Australia in 1940. Australian researchers introduced two parasitoid species collected in Thailand into Australia in 1990/1991 as biological control agents of this pest. Logvinoskaya (1983) described the female of one of these species, *Ageniaspis citricola*, from specimens reared from *Phyllocnistis citrella* in Vietnam.

Due to the great concern over the threat the citrus leafminer poses to the citrus industry, researchers have begun to search for effective parasitoids to introduce into Florida in order to mitigate damage caused by this pest (Hoy & Nguyen 1994). Dr. Marjorie Hoy of the University of Florida collected *A. citricola* in Australia in April 1994. The parasitoid was released in various sites in Florida later the same month. Males of *A. citricola* were discovered emerging from *P. citrella* specimens collected by Dr. Hoy in Australia.

Ageniaspis citricola Logvinoskaya
Figs. 1-6

Male:

Length: 0.9-1.1 mm, *Color*: Head, thorax and gaster, dark brown; all legs dark brown except yellow tarsi and distal one-third of mid and hind tibiae; fore wing hyaline with brownish submarginal and marginal veins and slight infuscation under marginal vein; radicle, scape, pedicel dark brown, F1-F3 light brown, F4-F6 and club yellow. *Structure*: Head as wide as thorax, lateral ocellus one ocellus diam from eye, mandible tridentate (Fig. 2) with sharp inner tooth; antennae (Fig. 3) with radicle, scape and pedicel, 2, 2.7 and 2 times longer than wide, respectively; funicle 6-segmented, all segments quadrate and subequal to each other, with the following numbers of longitudinal sensillae: F1:0, F2:1, F3:1, F4:2, F5:2; F6:3; club 1-segmented, 2.2 times longer than wide, with 4 longitudinal sensillae, apex rounded. Mesoscutum entire with longitudinal, semi-striate sculpture and about 45 setae; scutellum similar to mesoscutum in sculpture, with about 16 setae and small, round placoid sensillae about 4 times the diam of one sensillum apart from each other; endophragma fuscous, slightly shorter than length of scutellum. Fore wing (Fig. 1) broad, 2 times longer than



Figs. 1-6. *Ageniaspis citricola* 1) Fore wing ♂ 2) mandible ♂ 3) antenna ♂ 4) antenna ♀ 5) ovipositor 6) aedeagus.

wide; marginal fringe very short, about 0.07 times as long as greatest width of fore wing; costal cell with about 44 setae; speculum with two arrowhead-shaped setae; disk setae dense; submarginal vein long, about 9 times as long as marginal vein, with 10 setae and a small gap between it and the marginal vein; marginal vein shorter than postmarginal and stigmal veins; postmarginal vein 1.6 times longer than stigmal vein. Gaster short, aedeagus (Fig. 6) arising in the apical quarter of the gaster and less than one-half as long as mid-tibia. Ovipositor (Fig. 5) shown for comparison of sexual differences.

Specimens examined: 8 males, reared from *Phyllocnistis citrella* on *Citrus* sp., Australia, near Mundubbera, Queensland, 18 April 1994, M. Hoy.

DISCUSSION

The discovery of males of this species has major implications on rearing and colonization strategies for this parasitoid. Sexual dimorphism in this species is not as prominent as it is in most encyrtid species where males can often be distinguished from females based on differences in coloration and/or by the longer setae or rami of the male antenna. Males of this species are very similar to the females in shape and color and differ very little in the length of the antennal setae. The males can be most easily distinguished from the females by the shape of the F1 and F2 antennal segments (Fig. 3). These segments are very short, much broader than long, each only about one-half as long as F3 in females (Fig. 4); whereas in males these segments are quadrate, each about as long as F3.

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NEW DISTRIBUTIONAL RECORDS FOR *PLATYSTETHUS* (COLEOPTERA: STAPHYLINIDAE: OXYTELINAE) WITH NOTES ON THE BIOLOGY OF *P. AMERICANUS*

G. Y. HU AND J. H. FRANK
Entomology and Nematology Department, University of Florida,
Gainesville, FL 32611-0620, USA

ABSTRACT

A survey of the fauna of cattle dung dropped naturally on pasture in Alachua County, Florida, revealed several species of Staphylinidae, including two species of *Platystethus*. Adult *Platystethus spiculus* Erichson were collected only in July 1991. Adult *Platystethus americanus* Erichson were collected from March to June 1993. In the laboratory, immature stages of *P. americanus* took 18-22 days to develop at 27°C (2-3, 10-12, and 7 days for the egg, larval, and pupal stage, respectively). Some adults were offered cattle dung alone as diet in which the females deposited eggs in chambers. Some larvae were offered cattle dung and horn fly [*Haematobia irritans* (L.)] larvae as diet, and the beetle larvae pupated successfully in chambers or partial chambers under the dung. Adults and larvae held without cattle dung ate horn fly larvae, but females did not oviposit and beetle larvae did not pupate, most likely because they require dung or a similar substrate in which to make chambers. New distributional records are Florida and New Mexico for *P. americanus*, and St. Croix (U.S. Virgin Islands) and New Mexico for *P. spiculus*.

Key words: *Platystethus americanus*, *Platystethus spiculus*, Florida, predation, horn fly, cattle dung.

RESUMEN

Una investigación de la fauna que habita las deposiciones del ganado en pastos del condado de Alachua, Florida, reveló la presencia de varias especies de Staphylinidae, incluyendo dos especies de *Platystethus*. Los adultos de *Platystethus spiculus* Erichson se colectaron sólo en julio de 1991. Los adultos de *Platystethus americanus* Erichson fueron colectados desde marzo hasta junio de 1993. En el laboratorio, los estadios inmaduros de *P. americanus* tardaron 18-22 días para desarrollarse a 27°C (2-3, 10-12, y 7 días para los huevos, larvas y pupas, respectivamente). A un grupo de adultos se les ofreció deposición de ganado como dieta solamente, sobre la cual las hembras depositaron sus huevos en cámaras. A un grupo de larvas se les ofreció deposición de ganado y larvas de la mosca *Haematobia irritans* (L.) como alimento, y como resultado las larvas de los escarabajos puparon exitosamente en cámaras, total o parcialmente construidas debajo de la deposición. Los grupos de adultos y larvas de los escarabajos mantenidos sin deposiciones de ganado comieron las larvas de moscas ofrecidas, pero las hembras no depositaron huevos y las larvas no puparon, posiblemente debido a la falta del material de la deposición o de otro parecido para construir sus cámaras. Se lograron nuevos registros de distribución de *P. americanus* para la Florida y Nuevo México, y de *P. spiculus* para Santa Cruz (St. Croix, Islas Vírgenes Norteamericanas) y Nuevo México.

Results reported herein are part of a study on the arthropod community associated with cattle dung in Florida. No comprehensive study of the fauna of cattle dung has yet been reported for Florida. The doctoral dissertation of the senior author will, when completed, document many components of the fauna and their interactions; this paper deals only with the genus *Platystethus* and its role. The presence of certain arthropods, especially predatory Staphylinidae, in cattle dung has been shown elsewhere to reduce populations of the horn fly, *Haematobia irritans* (L.) (Blume et al. 1970, Thomas & Morgan 1972, Macqueen & Beirne 1975). We view an understanding of the fauna and the interactions in cattle dung in Florida as a necessary background to implementing biological control of horn fly.

MATERIALS AND METHODS

A survey of the arthropod community associated with cattle dung was conducted on pasture in July 1991 and from June 1992 to December 1993. The pasture is 16 km (10 miles) northeast of Gainesville, Alachua County, Florida, and had approximately 250 beef cattle at the time of the study. Two methods of collection were used: pitfall traps baited with fresh cattle dung, and emergence boxes that held entire dung pads and trapped all emerging arthropods. A dilute soap solution was added to the pitfall traps to drown trapped arthropods and keep them clean and flexible for subsequent processing. Ten to 15 pitfall traps were set twice each month from May to October, and once each month from November to April. Arthropods captured in the traps were collected after 24 hours and preserved in 70% alcohol for identification.

Between December 1992 and December 1993, cattle dung pads about 24 hours old were collected from the pasture and carried to the laboratory to extract the dung-associated arthropods. Five dung pads were sampled twice a month from May to October and once a month from November to April. The pads were placed individually into emergence boxes of a type described to us by G. T. Fincher (USDA-ARS, College Station, Texas). Each box was a gray plastic kitchen box 46 cm long x 33 cm wide x 18 cm high. A 30 x 20 cm^2 section was cut from each lid and replaced with a piece of black cotton cloth to provide ventilation. A circular hole (4 cm diam) was cut through one end of the box. The lid for a 7.5 cm high × 4 cm diam vial was perforated, then glued and riveted to the box over the hole. When the vial was screwed onto the cap, it served as a collection device to collect arthropods that attempted to escape the emergence box by flight. In a similar manner, a 10 cm diam hole was cut through the bottom of the box. The lid of a 12.7 cm deep × 12.7 cm diam plastic jar was perforated and glued and riveted over the hole in the box and then the jar screwed onto the jar lid. This device collected arthropods walking and falling into it. The mouth of the vial and the cup were each fitted with a hardware cloth funnel to prevent insects from escaping back to the box. The vial and the cup collected adult arthropods that left the dung in the emergence box. These arthropods either were in the adult stage when the dung was collected, or had developed from immature stages within the dung.

Adult *Platystethus americanus* Erichson from dung were confined in Petri dishes (5.08 cm diam x 1.27 cm high) to study their biology and predation behavior. Moist paper towel was placed on the bottom of each Petri dish. A water-soaked cotton ball was provided for humidity, and cattle dung and/or horn fly eggs or first instar larvae were provided for food. An observation cage as described by Hinton (1944) was also made for rearing *P. americanus* in the laboratory. The cage consisted of a well cut in a piece of styrofoam. The well was covered by a piece of microscope slide. The reproduction and development of the beetle at successive stages were recorded daily.

RESULTS AND DISCUSSION

Field Collections of Adults

In July 1991, six cattle dung pads (<2 hours old) were collected from the pasture and placed into emergence cages. Three pads were collected on grass and three on bare soil. Fifty-seven *P. spiculus* Erichson were extracted from two of the three pads on grass. Most *P. spiculus* were extracted within the first 48 hours after the dung pads were collected, and the last specimen was collected on the 19th day after the dung was sampled (Fig. 1).

Beginning in June 1992, Staphylinidae and other arthropods were captured in pitfall traps also. The first *P. americanus* specimens were trapped on 23 March 1993; more were collected in April-June, and none thereafter (Fig. 2). Fourteen *P. americanus* were captured in 9 of 60 traps (15% positive) from March to June 1993.

Extractions from dung pads provided one *P. americanus* from dung collected on 23 March 1993. The numbers increased in April and May, peaked in June, then declined quickly. Only one specimen was extracted from the pads collected on 30 June. No additional *P. americanus* specimens were found (Fig. 2). In total, 109 *P. americanus* were extracted from 15 of 30 (50%) dung pads during March through June 1993. As with *P. spiculus*, most of the *P. americanus* were extracted within the first 48 hours after the dung was sampled. Perhaps this indicates loss of attraction of the dung to the beetles as it decomposed.

Platystethus spiculus was collected only in July 1991, and *P. americanus* only in March-June 1993. We do not know the habitats of these species during the rest of the year. In a study conducted during June-September in Indiana, *P. americanus* was collected in each of those months, but less frequently in July (Sanders & Dobson 1966). In a study conducted in June-September in Nebraska, *P. americanus* was collected most frequently in early July (Schreiber et al. 1987). In a study conducted in Texas from March 1979 to December 1980, *P. americanus* adults were trapped in 1979 in April-October with peak numbers in July, and in 1980 in February-June with peak numbers in June (Hunter et al. 1991); the data for 1980 are similar to ours.

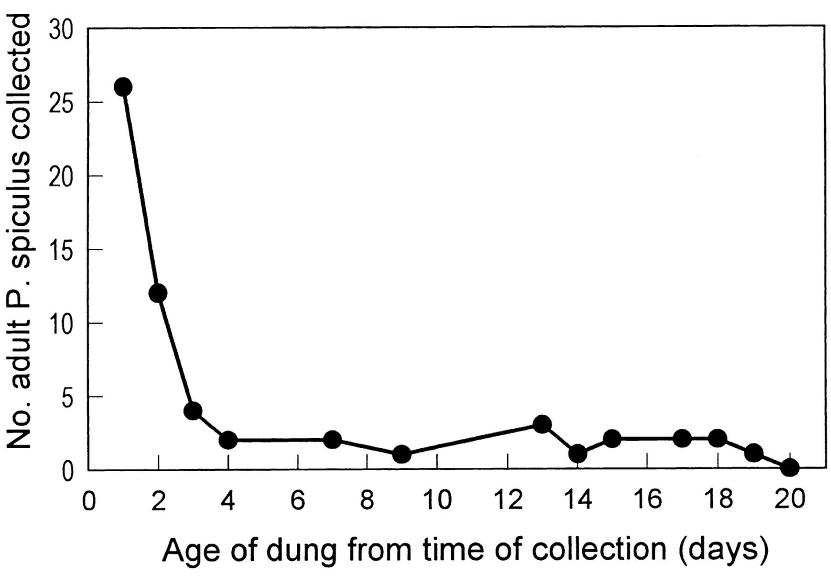

Fig. 1. Numbers of *Platystethus spiculus* adults extracted from 24-hr-old cattle dung placed into emergence boxes (n = 6) by day from date of collection. Most of these insects emerged from the dung in the first 48 hours.

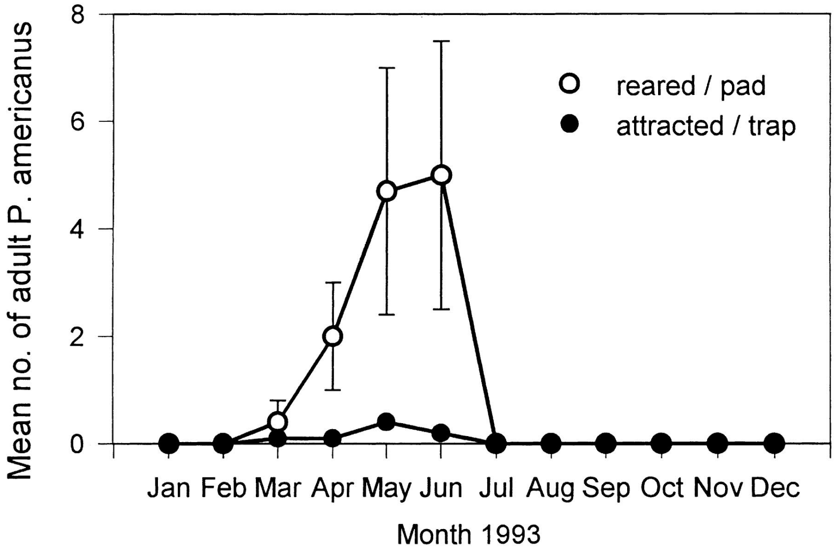

Fig. 2. Mean numbers of adult *Platystethus americanus* collected (a) by dung-baited pitfall traps in the field (n = 10 × 2 in May-October, 10 for the remaining months) and (b) from emergence boxes containing 24-hr-old cattle dung (n = 5 × 2 in May-October, 5 for the remaining months) by month.

Mating and Behavior of Female *Platystethus*

Two pairs of adult *P. americanus* were observed mating on the second and third day, respectively, after confinement in a Petri dish. One mating lasted 65 seconds and the other 80 seconds. The male at first was on the back of the female and twisted his abdomen back and forth about once per second. Then he moved until the two adults faced in opposite directions with tail to tail attachment for 10 to 20 seconds more until they separated.

Hinton (1944) described sub-social behavior by *P. arenarius* females. He observed that the female constructed a brood chamber in cattle dung, remained inside throughout the incubation of the eggs and, during the first few days of the life of the young larvae, she attacked other insects entering the chamber and protected her young against fungi. We observed that female *P. americanus* made two chambers, about 1 cm apart, connected by a gallery. One was a brood chamber with 3-5 eggs; it was about 5-7 mm in diam and about 5 mm deep. The female spent most of her time in the other chamber, or in the connecting gallery. We did not observe defensive or chamber-repairing behavior.

Eggs, Larvae, and Pupae of *Platystethus americanus*

The development time of the immature stages, from oviposition to adult emergence, was 18-22 days at 27°C. The egg is oval, colorless, and transparent. Its surface is smooth and without sculpture and measures approximately 0.48 x 0.24 mm. Incubation lasted 2-3 days. At 24 hours, two black (eye) spots could be seen near one end of the egg, and an embryo was visible. Three pairs of adults were reared in separate cages containing cattle dung.

First instar larvae of *P. americanus* were 1.5 x 0.26 mm in size and developed in 2-3 days. The second instar was 1.85 x 0.48 mm and developed in 2-3 days. The third was 2.71 x 0.57 mm (Fig. 3) and developed in 5-6 days.

The larva of *P. americanus* was described by Paulian (1941). The larva of *P. spiculus* was described by Legner & Moore (1977), and more completely, with the pupa, by Palomino & Dale (1989). These larvae are campodeiform, pale with the integument mostly transparent. The head and mouthparts are tinged with brown. In all members of the subfamily Oxytelinae the antenna has 3 segments, and the 2nd segment has a sensory appendage (Frank 1991) on the apico-medial aspect. In the larva of *P. americanus*, this appendage is only half as long as the 3rd segment. Legner & Moore (1977) and Palomino & Dale (1989) describe this appendage in *P. spiculus* as being as long as the 3rd antennal segment, making this a useful character to distinguish between the 2 species.

The pupa (Fig. 3) is exarate, 2.0 x 0.7 mm, yellowish-white, and very similar to the pupa of *P. spiculus* as described by Palomino & Dale (1989). This stage lasted 7 days, including a 1-day prepupal stage.

Food of *Platystethus*

The food range of *Platystethus* adults and larvae is unclear. Mohr (1943) assumed that *P. americanus* is a predator because it is a staphylinid, and Cervenka & Moon (1991), without providing evidence, considered it to be predatory. However, the family Staphylinidae includes fungivores as well as predators. *Platystethus arenarius* (Fourcroy) adults and larvae were observed by Hinton (1944) to ingest cattle dung, and were stated by Skidmore (1991) to feed exclusively on cattle dung. Larvae of *P. spiculus* were reported from cattle dung by Legner & Moore (1977). Frank (1976) found

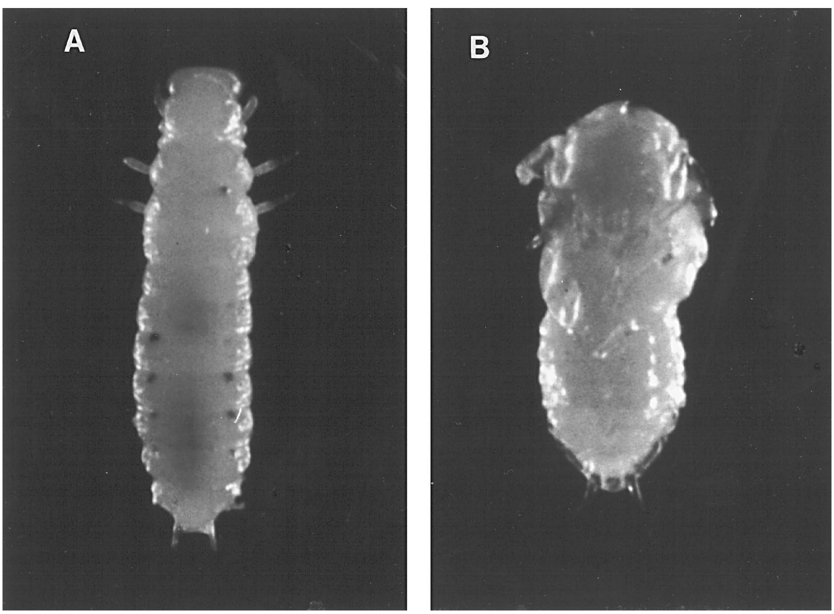

Fig. 3. Photographs of *Platystethus americanus*: (A) dorsal view of a third instar larva and (B) dorsal view of a pupa.

adult *P. spiculus* in horse dung, but many were discovered feeding on a slime mold [*Fuligo septica* (L.) Wigger]. Palomino & Dale (1989) reported collecting *P. spiculus* adults from cattle dung, obtaining eggs, and rearing larvae on a diet of house fly [*Musca domestica* (L.)] eggs (killed in hot water) in small Petri dishes; those authors provided wadded soft paper as substrate in the dishes (Palomino & Dale 1989) without any cattle dung (W. E. Dale pers. comm.).

We confined 10 adult *P. americanus* individually in Petri dishes and provided them with horn fly eggs and first instar larvae for food, without dung. Each beetle consumed 1.5 ± 1.02 (SD) first instar larvae of the horn fly per day (range 0-4 per day), leaving only the pharyngeal sclerites of the larvae in the dish; but we found no beetle eggs in the dishes. Horn fly eggs were not eaten. However, when adults were offered only cattle dung, they survived and the females made chambers in the dung and oviposited in these. This shows that dung (or fungi growing in the dung) provides an adequate diet, but does not prove that fly larvae are an inadequate diet; the failure of females to lay eggs probably was because we failed to provide a substrate in which the females could form chambers for oviposition.

When five *P. americanus* larvae were placed in Petri dishes with horn fly eggs and larvae but no cattle dung, feeding on first instar fly larvae occurred, and the beetle larvae developed but did not pupate. Horn fly eggs were not eaten. However, when beetle larvae were reared with cattle dung and horn fly eggs and larvae, they pupated successfully in chambers or partial chambers under the dung. This suggests only that larvae will not pupate unless provided with an appropriate substrate in which to form pupation chambers.

The trichotomy of coprophagy-mycophagy-predation has not been resolved experimentally in any *Platystethus* species, nor yet by us. However, the coprophagy may be only apparent, for while the insects may ingest dung, they may be digesting fungus, for which the dung provides a substrate. We now believe that oviposition and pupation in chambers, formed by the adult females and prepupae respectively, are obligate behaviors in *P. americanus*. Palomino & Dale (1989) showed that *P. spiculus* will accept a paper substrate in place of dung in which to make these chambers. We believe that the paper towel we placed in Petri dishes was not of suitable texture or bulk, and could not be excavated to form chambers.

Finally, the lack of *Platystethus* adults (and larvae) in cattle dung throughout the year at the study site suggests that dung is not the principal habitat, but is merely an additional habitat which is used in seasons of higher temperature and humidity when dispersal flight by adults occurs.

Geographical Distribution

The world fauna contains 48 species of *Platystethus* (Herman 1970), of which 3 now occur in the USA. *Platystethus americanus* has a Nearctic distribution, ranging as far north as British Columbia and Quebec. Earlier records are summarized by Blume (1985). Our finding of it in Alachua County is the first record for Florida. Three specimens sent to J. H. Frank for identification in 1988 seem to be the first record of *P. americanus* for New Mexico; they were labelled: New Mexico, Dona Ana County, 30-V-1987, dairy, coll. T. Carrillo.

Platystethus cornutus Gravenhorst is a Palearctic species whose discovery in Nebraska by Moore & Legner (1971) was the first record for the USA. It was reported from Ohio by Moore (1976).

Platystethus spiculus is widely distributed in Neotropical countries (Blackwelder 1943). It was identified from Bermuda by J. H. Frank, reported by Hilburn & Gordon (1989). Two specimens collected at a U.V. light trap give the first records for the US

Virgin Islands: St. Croix, Northside A, Sprat Hall, 23-VI-1991, and Westend, Brooks Hill, 24-VI-1991, coll. J. H. Frank (the specimens are in the collection of J. H. Frank). It seems to reach the northern limit of its range in the southern tier of states in the USA. It has been reported from Texas (Casey 1886), California and Arizona (Moore & Legner 1971), and Florida (Frank 1976). A specimen sent to J. H. Frank for identification in 1986 by G. H. Kinzer (New Mexico State University) seems to be the first record of *P. spiculus* for New Mexico: it was collected in cattle dung on the Jornada Experimental Range in Dona Ana County (the date of collection was not given). Moore & Legner (1971) provided a key to the adults of these 3 species. Frank (1976) supplemented that key by noting sexual dimorphism in the characters of the head.

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SPECIFICITY OF THE RED IMPORTED FIRE ANT (HYMENOPTERA: FORMICIDAE) PHAGOSTIMULANT RESPONSE TO CARBOHYDRATES

R. K. VANDER MEER, C. S. LOFGREN AND J. A. SEAWRIGHT
USDA/ARS
Medical and Veterinary Entomology Research Laboratory
P.O. Box 14565
Gainesville, FL 32604 USA

ABSTRACT

The red imported fire ant, *Solenopsis invicta* Buren, is considered an oil-loving feeder, however, carbohydrates are essential ingredients in the diet of the fire ant also. Comprehensive screening of mono-, di-, and tri-saccharides demonstrated that glucose, fructose, fucose, sucrose, maltose, turanose and raffinose were significant phagostimulants for fire ant workers. It was also found that while D-glucose and L-fucose, the naturally occurring isomers, were active, the opposite diastereomers were not. Any structural modification of the glucose molecule resulted in loss of activity. None of the sugar alcohols evaluated were active. The fire ant is an agricultural pest and the many reports of fire ant damage to food crops may be linked to their need for dietary carbohydrates. A knowledge of carbohydrate phagostimulants may help to understand specificity of fire ant /plant interactions.

Key Words: Feeding, sugars, *Solenopsis invicta*, diet, agriculture

RESUMEN

La hormiga de fuego, *Solenopsis invicta*, era considerada como una de las que gusta de alimentarse de aceite. Sin embargo, a partir de estudios de laboratorio se hizo evidente que los carbohidratos eran ingredientes esenciales en la dieta de estas hormigas. Estudios de tamizaje de mono- di-, y tri-sacáridos demostraron que la glucosa, fructosa, fucosa, maltosa, turanosa y rafinosa fueron fagoestimulantes de las obreras de las hormigas de fuego. Se encontró además que mientras que la D-glucosa y la L-fucosa, los isómeros de aparecen en la naturaleza, eran activos, los diastereómeros opuestos no lo eran. Cualquier modificación estructural de la molécula tuvo como resultado pérdida de actividad. Ninguno de los alcoholes de los azúcares evaluados fué activo. La hormiga de fuego es una plaga agrícola y muchos reportes de daños por las hormigas a los cultivos deben relacionarse con su necesidad de carbohidratos. El conocimiento de los fagoestimulantes carbohidratados puede ayudar a entender la especificidad de las interacciones de las hormigas de fuego con las plantas.

The red imported fire ant, *Solenopsis invicta* Buren, was accidently imported into the United States in the 1930's from South America. Since then it has spread to infest over 150 million hectares in nine southern states and Puerto Rico (Lofgren 1986a). Its potential spread includes Arizona, California, Oregon and Washington; however, the deserts of Texas and stringent quarantine measures currently restrict its spread (Lofgren 1986b). Mature fire ant colonies contain up to 250,000 workers and 120 colonies may infest each hectare. The ant behaves like a "weed species", thriving in disturbed habitats (farmland, pastures, around homes, and playgrounds) where contact with man is frequent (Tschinkel 1987). It is the high population density and sympatry with man's activities that have made the fire ant one of the most important medical and agricultural pest ant species (Adams 1986).

The highly aggressive workers have a potent sting and the injected venom has a wide variety of physiological effects, the most severe of which is hypersensitivity. As with honey bees, about one percent of the population may develop allergic reactions and each year about one-third of the people in infested areas are stung. Consequently, the number of hyperallergic cases is much higher than for bee stings (Adams & Lofgren 1981). Even without an allergic reaction, the stings are painful and curtail people's outdoor activities.

The fire ant is agriculturally important because it is an opportunistic omnivore that has an excellent food recruitment system (Vander Meer 1986). The workers attack a wide variety of crops including soybeans, potatoes, corn, citrus, and okra. They feed on germinating seeds in corn and soybean fields, thus decreasing the crop yield (Adams 1986). This kind of damage was noted soon after research began on the imported fire ants (Wilson & Eads 1949); however, the extensive use of persistent chlorinated hydrocarbon insecticides in the 1950's and 1960's subdued the agricultural effects of fire ants until these residual compounds dissipated in the 1980's to the present (Adams 1986).

Fire ants are considered a "grease or oil loving" ant and toxic baits were developed for fire ant control based on a vegetable oil phagostimulant/active ingredient solvent (Banks et al. 1985). However, feeding studies have also indicated the importance of carbohydrates in the fire ant diet (Lofgren et al. 1961; Ricks & Vinson 1970), and it has been shown that honey-water added to the standard laboratory diet enhanced both colony weights and queen survival (Williams et al. 1980). In addition, several food preference studies have also indicated the importance of dietary carbohydrates (Vinson 1968; Howard & Tschinkel 1981; Sorensen & Vinson 1981). In many other insects, the larval stages do not require dietary carbohydrates, instead relying on amino acid and fatty acid oxidation for their energy needs. In contrast, adults usually consume large amounts of carbohydrates (Chippendale 1978).

We report here results of carbohydrate phagostimulant tests that define the scope of effective sugar feeding stimulants and the specificity of the taste receptors of the ant for the structural integrity of naturally occurring carbohydrates.

MATERIALS AND METHODS

Source of Colonies

Laboratory colonies of *S.invicta* were reared from newly mated queens collected near Gainesville, Florida using standardized procedures (Banks et al. 1981). Each colony attained an estimated population of at least 50,000 workers prior to use in phagostimulation bioassays.

Carbohydrate Phagostimulant Bioassay

The bioassay was similar to one already described for assessing fire ant recruitment/aggregation (Vander Meer et al. 1988). Colonies with two or more nest cells (10,000 to 20,000 workers each) were used for the bioassays. A colony nest cell and foraging workers were transferred to the center of a clean bioassay tray. Worker ants were allowed to acclimate at least one h before testing. Each of the five replicates consisted of a different colony. No attempt was made to manipulate the ratio of larvae to workers nor to assess the condition of the queen, except to periodically determine if she was still producing eggs and worker brood. The bioassay trays had numbered positions from 1 to 10 marked equidistant from each other and in a 15 cm radius from the tray center. The tray sides were painted with Fluon^{R} to prevent ant escape. Whatman Phase Separator filter paper squares (2×2 cm), were placed on slightly larger aluminum foil squares that protected the tray from sample contamination. A water control and 1% (W/V) sucrose standard were included in each test, thus a total of 8 treatments could be evaluated for each replicate. All samples, standard, control and treatments were applied (100uL) to the center of the phase separator filter paper squares and then randomly placed around the ten symmetrical locations on the tray floor. Bioassays were carried out at about 30°C with a variable light/dark cycle.

All sugars, sugar alcohols, sugar derivatives and artificial sweeteners (Sigma Chemical Company, St. Louis, Missouri or Calbiochem, La Jolla, California) tested were prepared as one percent (W/V) aqueous solutions. The chemical names for all compounds tested appear in the Figures.

The bioassay was evaluated by counting the number of ants feeding at the droplet every 10 minutes for a total of 60 minutes. The results for the six time periods were added and the total used to calculate the ranking. The test samples were ranked by setting the water response at zero and the sucrose response at 100. This nullified much of the natural colony to colony variation and allowed comparison of results from one test to another. The ranking was calculated as follows:

$$\frac{(\text{No. ants, sample}) - (\text{No. ants, } H_2O \times 100)}{(\text{No. ants sucrose}) - (\text{No. ants } H_2O)}$$

The mean and standard error for five replicates was calculated for each treatment. After each bioassay the colony cells were returned to their rearing trays. The same sets of colonies were used multiple times for the bioassays.

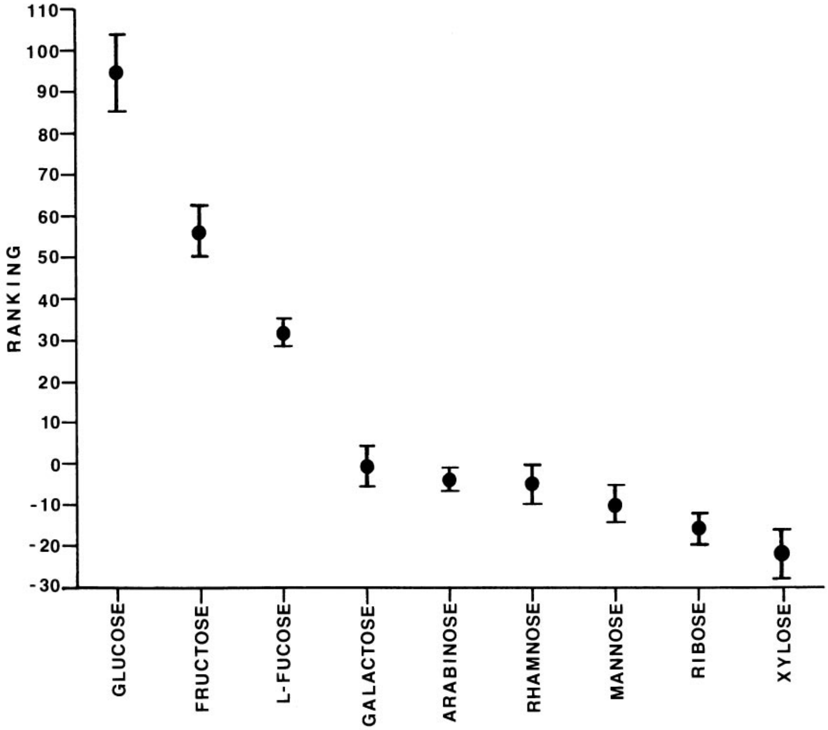

Fig. 1. Phagostimulant bioassay results for monosaccharides (Ranking based on sucrose = 100; and water = 0). The mean and standard error of five replicates are presented.

RESULTS

Carbohydrate Phagostimulant Tests

Nine naturally occurring monosaccharides were tested for phagostimulant activity. Of these, only D-glucose, D-fructose, and L-fucose had significant phagostimulant activity (Fig. 1). All others had activity either indistinguishable or below that of the water control. The glucose result was indistinguishable from that of the sucrose standard (Ranking = 100%). All three active monosaccharide phagostimulants were significantly different from each other.

D-Glucose was clearly the most effective of the monosaccharides tested, we then conducted phagostimulant tests with eight chemically modified glucose compounds to determine what affect structural changes would have on fire ant phagostimulation. The structures are shown in Fig. 2 and the bioassay results are shown in Fig. 3. Substituting sulfur for oxygen, 1-thio- and 5-thio- resulted in no significant phagostimulation activity. Similarly, removal of a hydroxyl group (2- and 6-deoxy-) reduced the activity to insignificant levels. Mono or di-phosphorylation gave no phagostimulation activity. Only 2-deoxy-2-fluoro-glucose, 5-thio-glucose and glucose-1, 6-diphosphate had mean activity scores above that of the water control.

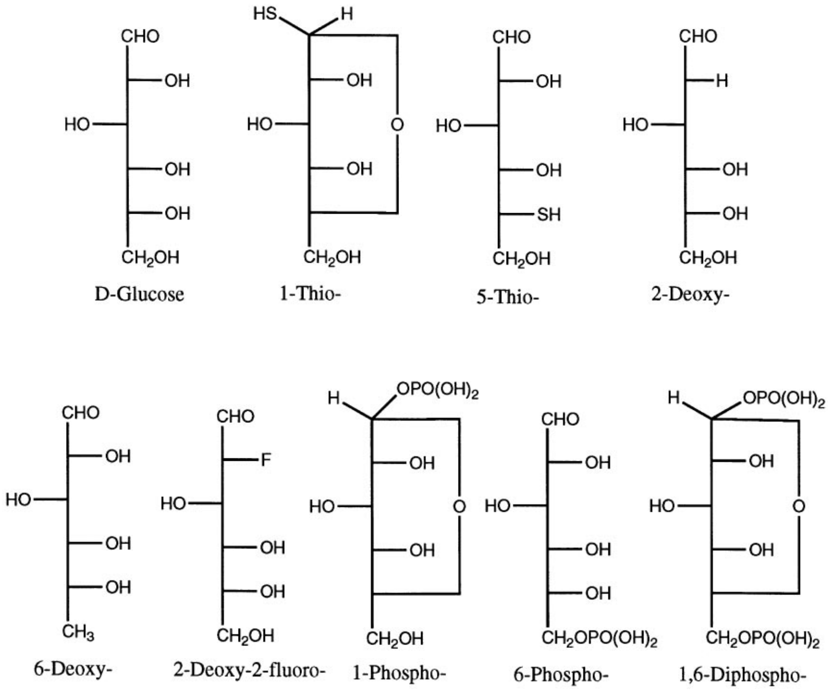

Fig. 2. Chemical structures of glucose and the glucose derivatives tested for phagostimulant activity.

The opposite enantiomers of several of the naturally occurring monosaccharides shown in Fig.1 were tested in the phagostimulation bioassay. The two enantiomers of each compound have identical physical and chemical properties. They differ only in that they rotate plane polarized light in opposite directions. The results are shown in Fig. 4. Naturally occurring D-glucose and L-fucose were active phagostimulants; however, the opposite enantiomers were inactive. Both unnatural enantiomers of the monosaccharides, mannose and arabinose were inactive in the phagostimulation bioassay as were their natural counterparts.

Results for seven disaccharides and one trisaccharide tested for phagostimulation activity are shown in Fig. 5. The three disaccharides, sucrose, maltose, and turanose had excellent phagostimulant activity. Maltose had activity equal to that of the sucrose standard, while turanose was only slightly below the standard. The one trisaccharide, raffinose, tested had good phagostimulant activity, although less then the active disaccharides.

Nine sugar alcohols were tested (Fig. 6). Only myo-inositol had greater activity than the water control, but it still ranked far below the phagostimulant activity of the sucrose standard (13 vs. 100). The two enantiomers of arabinitol were tested, but each showed equally poor phagostimulation results.

Discussion

Relatively soon after their accidental importation into the United States, fire ants were reported to feed on the seeds of corn, peanuts, and beans, as well as crop seed-

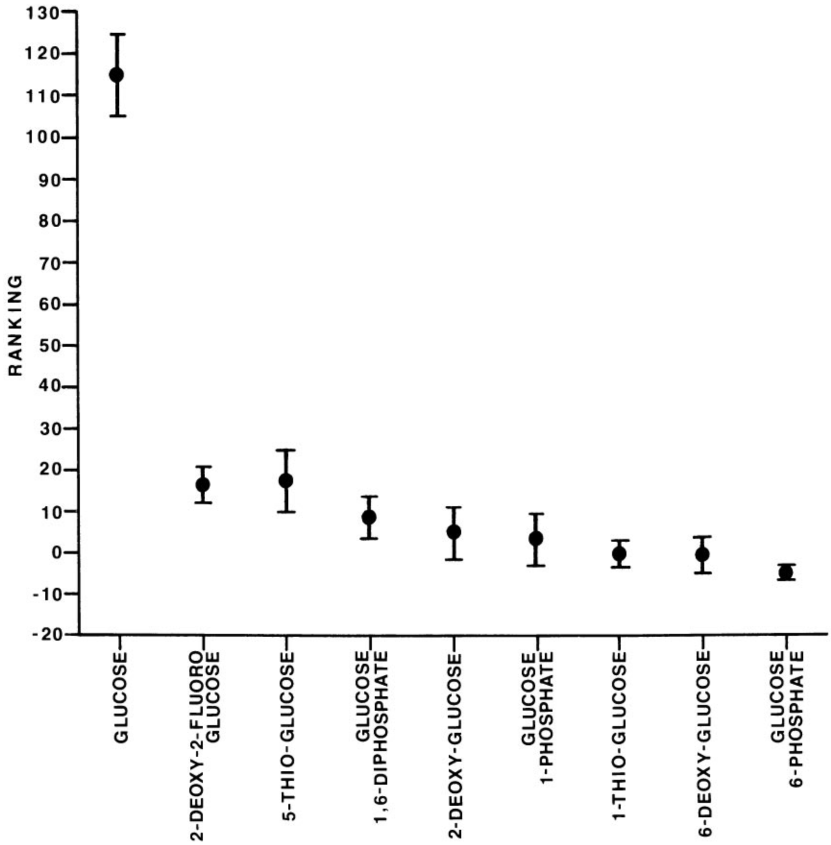

Fig. 3. Phagostimulant bioassay results for glucose and its derivatives (Ranking based on sucrose = 100; and water = 0). The mean and standard error of five replicates are presented.

lings (Wilson & Eads 1949). More recent studies have described significant loss of soybean yields due to fire ant infestations (Adams et al. 1983). In addition, studies using the radioisotope phosphorous-32 (^{32}P) demonstrated that the fire ant workers feed on corn, okra and soybeans (Smittle et al. 1983). The nature of the ^{32}P feeding experiment dictated that the radiolabel was obtained by the workers via ingestion of aqueous solutions. The authors observed that although fire ants were not observed feeding on okra seedlings or soybeans, the ants in the immediate vicinity had high levels of radioactivity. They concluded that the ants were feeding extensively on the plant roots. Similar experiments demonstrated that the ants feed on citrus (Smittle et al. 1988). Tennant & Porter (1991) examined the crop contents of returning foraging workers and concluded that carbohydrates represented a large proportion of what was being brought back to the colony. These authors suggest that the fire ant must be feeding on plant roots and/or the exudate from root associated coccids. All of the above emphasize that the fire ant is much more than an oil loving ant and that phagostimulant effects of water soluble substances may play a dominant role in directing their interactions

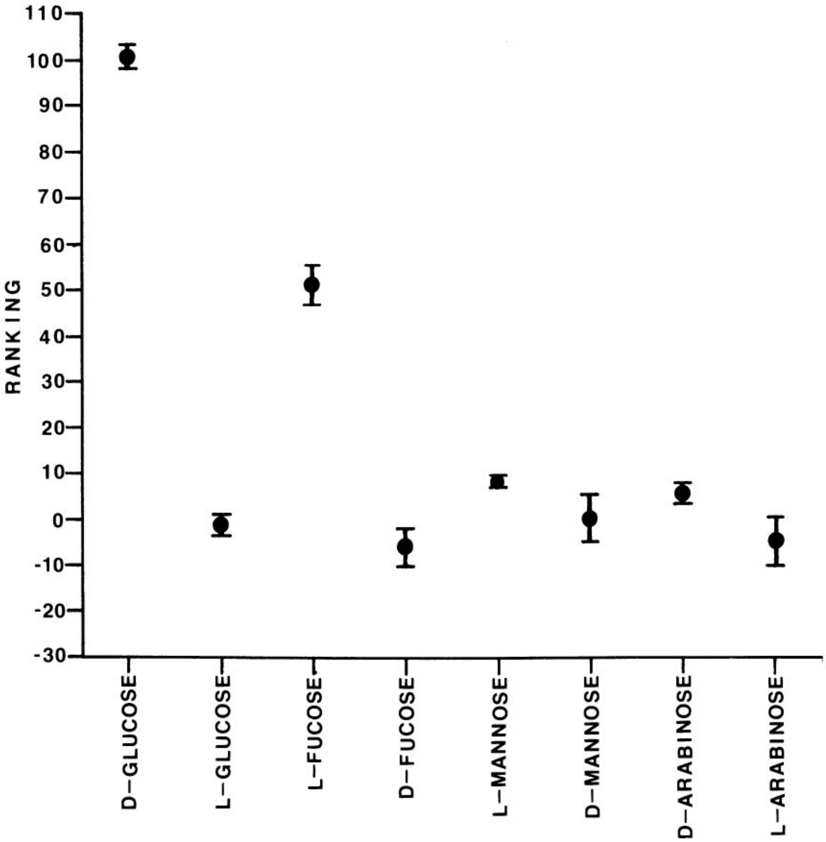

Fig. 4. Phagostimulant bioassay results for naturally occurring monosaccharides and their diasteriomers (Ranking based on sucrose = 100; and water = 0). The mean and standard error of five replicates are presented.

with plants. No comparison of phagostimulant activity was made between an aqueous sucrose solution (carbohydrate) and soybean oil (an oil), however, it is clear that both elicit strong recruitment (R. K. V. M., personal observation). When the interaction is with crop plants, then the fire ant becomes an agricultural pest. An understanding of phagostimulation and its specificity can provide insight into feeding preferences and may help us to develop better bait formulations.

A previous report investigated the phagostimulant effects of aqueous extracts of arthropods, amino acids, vitamins, and sugars (Ricks & Vinson 1970). The studies were carried out with the dark and light varieties of imported fire ant, *Solenopsis saevissima richteri*. These two forms probably corresponded to what is currently known as *S. richteri* and *S. invicta*, respectively (Buren 1972). In spite of different experimental conditions and evaluation procedures, our results for the same sugars were mostly congruent. The two exceptions (out of 11) were that we did not find phagostimulant activity for trehalose, and we found that fructose was an active phagostimulant. However, fructose was active for the dark phase of imported fire ant (Ricks & Vinson

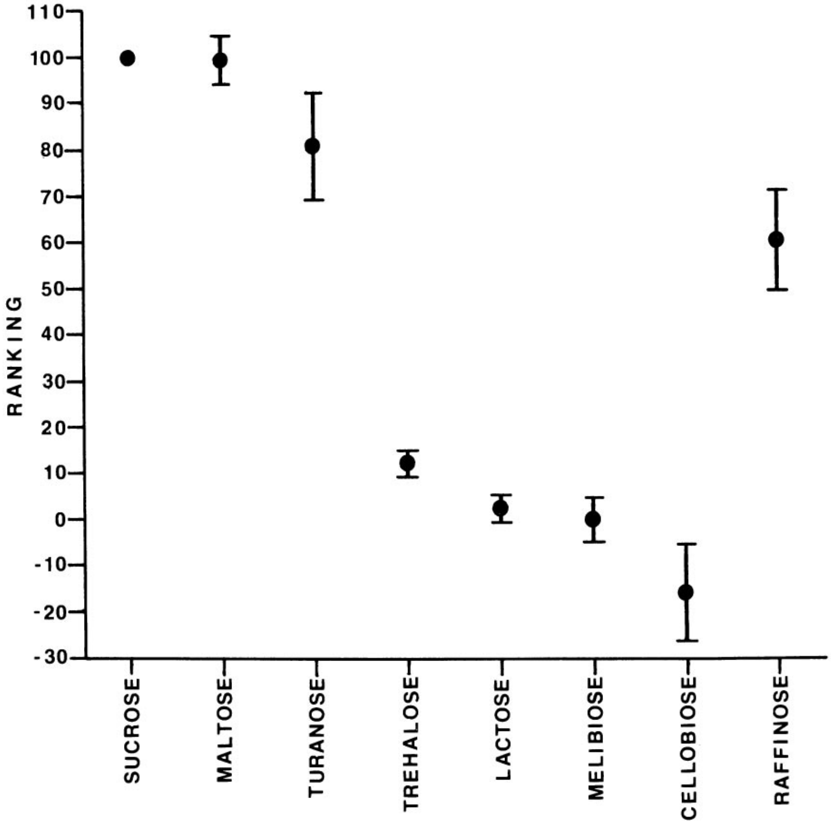

Fig. 5. Phagostimulant bioassay results for disaccharides and one trisaccharide (Ranking based on sucrose = 100; and water = 0). The mean and standard error of five replicates are presented.

1970). Of the additional sugars and sugar alcohols evaluated in our bioassay only turanose and L-fucose were found to be phagostimulants.

The fire ant has an excellent recruitment system (Vander Meer 1986), thus worker numbers can accumulate at a food source by either additive independent discoveries or by recruitment of workers. Initial discovery could be the result of random foraging or of attraction to volatiles emitted by the food source. In our bioassay the carbohydrates are non-volatile; however, the workers could be attracted to water vapor. Initial contact with treatments and water control are expected to be identical. After discovery, the quality of the food is evaluated, most likely through chemo-and mechanoreceptors at the tips of the labial and maxillary palps. Feeding is initiated if the sensory input is favorably interpreted by the central nervous system (CNS). Water was the common carrier of the phagostimulants in our bioassay, therefore, the response of workers coming in contact with the treatments was dictated by chemoreceptors and the translation of the interpretation of the CNS into feeding behavior. We do not know if the test compounds were all detected by the ant's chemoreceptors, but interpreted

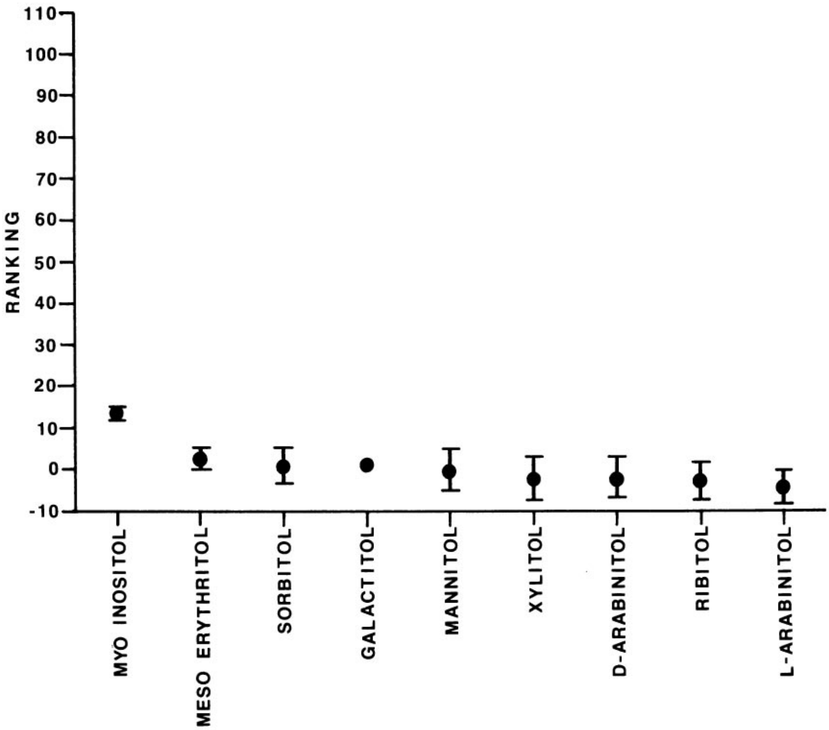

Fig. 6. Phagostimulant bioassay results for several sugar alcohols (Ranking based on sucrose = 100; and water = 0). The mean and standard error of five replicates are presented.

differently by the CNS, or if the compounds were differentially detected (see Bernays and Simpson 1982 for general review).

The sensitivity of the fire ant worker to changes in phagostimulant structure is clear from our results. L-fucose (6-deoxy-L-galactose) and L-rhamnose (6-deoxy-L-mannose) are naturally occurring deoxyaldoses. L-fucose was one of three monosaccharides that showed phagostimulant activity. Rhamnose was inactive. Neither monosaccharide from which these were derived, galactose and mannose, showed phagostimulant activity. In sharp contrast to the excellent phagostimulant activity of glucose, 2-deoxy- and 6-deoxy-D-glucose were also inactive. It is evident from Fig. 3 that any chemical modification to the glucose structure eliminates phagostimulant activity. The structural changes reflected in these compounds are obvious and lead to differences in physical properties, e.g. spectra (IR, NMR), melting point, and solubility. It is logical that the variation of molecular fit of these compounds with taste receptors and/or the CNS interpretation is reflected in the phagostimulation scores. This is most dramatically illustrated by the lack of phagostimulant response of worker ants to the unnatural diasteriomers of glucose and fucose. In this case the structural changes do not result in differences in physical properties. However, all chiral centers have the opposite configuration.

These data reveal that *S. invicta* can distinguish, by taste, a wide variety of carbohydrates. These carbohydrate phagostimulants may play important roles in the fire ant's choice of food, especially from plant sources. Glucose, fructose, and sucrose are known components of plant nectars (Lanza 1991, Lanza et al. 1993) and have been shown to act as phagostimulants in nectars and other plant fluids fed on by ants. Investigation into the stage of plant development susceptible to fire ant damage and the carbohydrate content of that stage may reveal a rationale for the selective agricultural impact of the fire ant.

Acknowledgment

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BIOLOGY OF THE SWEETPOTATO WHITEFLY (HOMOPTERA: ALEYRODIDAE) ON TOMATO

JORGE SALAS AND OMAR MENDOZA
FONAIAP. Centro de Investigaciones Agropecuarias del Estado Lara.
Apartado Postal 592. Barquisimeto, Venezuela

ABSTRACT

Development and oviposition of the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), were studied on tomato leaflets under laboratory conditions (25°C and 65% R.H.). Three nymphal instars and a transitional form were noted. The duration in days of the egg, nymphs and transitional form was: egg 7.3 ± 0.5; first instar 4.0 ±1.0; second instar 2.7 ± 1.1; third instar 2.5 ± 0.7; fourth instar-pupa 5.8 ± 0.3. Total life cycle from egg to adult emergence was 22.3 days. Adult longevity was 19.0 ± 3.3 and 19.4 ± 5.8 for the females and males, respectively. Preoviposition lasted 1.4 ± 0.7 and oviposition 16.7 ± 3.2 days. Fecundity was 194.9 ± 59.1 eggs per female, while egg viability was 86.5%. Sex ratio was 1: 2.7 male-female. Virgin females were parthenogenetic, arrhenotoky type.

Key Words: Life cycle, *Bemisia tabaci*, developmental stages, tomato, Venezuela

RESUMEN

El desarrollo y la ovoposición de la mosca blanca de la batata, *Bemisia tabaci* (Gennadius), fueron estudiadas en foliolos de tomate *Lycopersicon esculentum* bajo condiciones promedios de 25°C de temperatura y 65% de humedad relativa, a nivel del laboratorio. La duración en días de las diferentes fases de desarrollo fue: huevo 7,3 ± 0,5; primer instar ninfal 4,0 ± 1,0; segundo instar 2,7 ± 1,1; tercer instar 2,5 ± 0,7; cuarto instar-pupa 5,8 ± 0,3. La duración total del ciclo de vida desde huevo hasta la formación del adulto fue de 22,3 días. Se determinaron tres instares ninfales y uno de transición (cuarto instar-pupa). La longevidad de las hembras y los machos fue de 19,0 ± 3,3 y 19,4 ± 5,8 días, respectivamente. El período de preovoposición fue de 1,4 ± 0,7 días, mientras que el de ovoposición fue de 16,7 ±3,2 días. La fecundidad fue de 194,9 ± 59,1 huevos/hembra, siendo la viabilidad de los huevos 86,5%. La proporción sexual fue 1: 2,7 macho-hembra. Las hembras mostraron una partenogenesis, tipo arrenotoquia.

The sweetpotato whitefly, *Bemisia tabaci* (Gennadius), is one of the most important agricultural insect pests in the Middle East, Europe, North and Central America, and the Caribbean Basin. In addition to feeding on more than 700 host plant species within 86 botanical families (Greathead 1986), *B. tabaci* has a high reproductive capacity and distinctive life habits that enable it to (1) cause severe damage through plant feeding and (2) transmit more than 90 types of virus diseases in commercial crops (Brunt 1986).

On a worldwide basis, but mainly in the Old World, *B. tabaci* has been recognized as a major agricultural pest for more than four decades (Byrne et al. 1990). In the New World, its presence as an economic pest has been reported from the 1930s through the 1960s, with population outbreaks in the 1970s and 1980s up to the present date (Brown 1990). In Venezuela, population explosions on melon plantings in the late 1980s caused economic damage; tomato, tobacco, sesame and other annual crops were also damaged in the early 1990s (unpublished data).

Several studies on the biology of *B. tabaci* have been done under diverse environmental conditions, (López-Avila 1986). Those studies reported that the life cycles varied mainly depending upon the temperature, relative humidity and the host plant. Russell (1975) compiled literature on the biology and morphology of *B. tabaci* and other whitefly species in legume crops. She reported finding much variability in the life cycle and other biological aspects that were strongly related to climatic factors and the host plant. This study was conducted to determine the development and ovipositional preference of *B. tabaci* under controlled climatic conditions on tomato, *Lycopersicon esculentum* Mill.

MATERIALS AND METHODS

Bemisia tabaci was determined by L.M. Russell from U.S.D.A., A.R.S., S.E.L., Beltsville, M.D., U.S.A. (Arnal et al. 1993). Voucher specimens have been deposited in the Entomology Museum at FONAIAP, CENIAP, Maracay, Venezuela. We believe that the strain involved in this study is strain A (cotton strain). Venezuelan strains of *B. tabaci* are actually under study by J. K. Brown from University of Arizona, U.S.A. So far, plant symptoms caused by the B or “silverleaf” strain on several vegetable crops have not been observed in Venezuela.

The research was conducted at the Entomology Laboratory of FONAIAP - Centro de Investigaciones Agropecuarias del Estado Lara, Venezuela, in 1993 under a mean temperature of 25°C and 65% R. H. Initially, pupae of *B. tabaci* were collected from 'Rio Grande' tomato plantings located at Quíbor Valley, Estado Lara. Pupae were held in humidity chambers until the adults emerged. The adults were then placed on young healthy tomato plants (free of insects) which were kept inside of rearing and reproduction cages (50 × 40 × 40 cm) made of wood and organdy cloth.

Insect development was studied on 'Rio Grande' tomato leaves with at least three leaflets, which were placed inside glass vials 9.5 cm long and 2.5 cm wide. Ten to 20 adults were introduced into each vial and the vial was closed with a cotton plug. Subsequently, 84 eggs were observed to determine their incubation period. After hatching, 65 first instar nymphs were selected to study duration of that stadium; 30 of these were observed to determine the duration of the "crawling" period of the first instar. To determine the number and duration of each instar, we made direct observations of the molted exuviae with aid of scotch tape. The tape was placed carefully over nymphs located on the underside of the leaflets and just over the trichomes to avoid any injury to the nymphs. The nymphs and the scotch tape were checked daily to evaluate nymphal development and the presence of molted skins on the tape. These observations lasted until pupae were formed. Records were kept for the duration of each instar and the number of shed exuviae.

The duration of the transitional fourth instar-pupa stage was studied on 42 specimens showing combined morphological characteristics of nymph and pupa (typical "dome" shape of the nymph and the big red eyes of the pupa) through adult formation. Adult longevity was studied with 45 virgin males and 43 virgin females. They were placed individually inside the glass vials using tomato leaflets as food.

Preoviposition and oviposition periods and fecundity were studied with 40 virgin females sexed by body size and the shape of their abdomen. They were placed inside glass vials containing healthy tomato leaflets and the vials closed with a cotton plug. The petiole of each leaflet was inserted inside a small plastic container filled with water. The leaves were replaced daily. Viability was determined for 104 eggs laid by virgin females on 10 leaflets. Hatching was recorded daily. Sex was determined by the dissection of genitalia. Sexual structures were contrasted with the abdomen shape in every specimen. Sex ratio was observed and recorded for 220 adults of the same cohort based on dissection of genitalia. Parthenogenesis was studied on the offspring of 74 adults obtained from 20 previously isolated virgin females. Their sex was determined by dissection and observation of the genitalia.

Results and Discussion

Duration of the Developmental Stages

Mean duration of the egg and nymphal stage of *B. tabaci* is shown in Table 1. The egg incubation period, 7.3 ± 0.5 (S.D. is used throughout), was very similar to that reported by López-Avila (1986) for whiteflies reared on tomato and cotton at 25°C and 75% R.H., and Peña-Rojas et al. (1992) with common bean plants at temperatures ranging from 22 to 31°C and R.H.'s from 41.5 to 94%. This was different than that reported by Eichelkraut & Cardona (1989) for whiteflies reared on common bean plants grown in field (24°C, 70% R.H.) or greenhouse (26°C, 67% R.H.). A wide range in incubation period has been reported (3 to 33 d), depending mainly on temperature and relative humidity conditions (Husain 1931, Husain & Trehan 1933, Avidov 1956, El-Helaly et al. 1971, Azab et al. 1971, Butler et al. 1983).

The nymphal stage was separated into three well defined instars. A 4th-instar was considered as transitional and named 4th instar-pupa because the duration between these two stages was short and difficult to separate. The first instar lasted 4.0 ± 1.0 d

TABLE 1. MEAN DURATION OF THE DIFFERENT DEVELOPMENTAL STAGES OF *B. TABACI* REARED IN LABORATORY (25°C, 65% R.H.). 1993.

		Duration (days)[2]	
Stage	No. Tested	Mean ± SD	Range
Egg	84	7.3 ± 0.5	6.8 - 8.7
Nymph			
1st instar[1]	65	4.0 ± 1.0	2.5 - 7.0
2nd instar	55	2.7 ± 1.1	1.5 - 6.0
3rd instar	47	2.5 ± 0.7	1.5 - 4.0
4th instar-pupa	42	5.8 ± 0.3	4.0 - 9.0
Adult			
Male	45	19.4 ± 5.8	14.5 - 29.0
Female	43	19.0 ± 3.3	12.8 - 29.0

[1]The mobile form (crawler) lasted 1 h, 48 min, and the fixed form 4.0 d.
[2]Total life cycle from egg to adult lasted 22.3 d.

with two forms, one mobile (crawler) that lasted 0.08 d (1 h,48 min) and a fixed one that lasted 3.96 d. Duration of the crawler form was similar to that found by Eichelkraut & Cardona (1989), but Avidov (1956) indicated that it could last several days. Azab et al. (1971) found that the duration of the first instar varied from 2 to 6 d on sweetpotato under conditions close to ambient. Sharaf & Batta (1985) reported that the duration at 25°C was 2.8 d, and 9.0 d at 14°C.

Second and third nymphal instars lasted 2.7 ± 1.1 and 2.5 ± 0.7 d, respectively. These observations are similar to those reported by El-Helaly et al. (1971) on sweetpotato and potato under a temperature of 24.5°C and a saturated atmosphere and Sharaf & Batta (1985) at 25°C. It was different than the results reported by Eichelkraut & Cardona (1989) who found a duration of 4.7 and 3.7 d (2nd instar), and 5.9 and 5.1 d (3rd instar) on field and greenhouse, respectively, and Peña-Rojas et al. (1992) 4.45 d (2nd instar) and 4.35 d (3rd instar). Azab et al. (1971) reported that these instars lasted from 1 to 7 d for each; however, others reported that the whole nymphal stage lasted from 9 to 84. They emphasized that temperature had an important effect on the duration (Husain 1931, Husain & Trehan 1933).

Some researchers consider the 4th instar separate from the pupa (Azab et al. 1971, El-Helaly et al. 1971, Sharaf & Batta 1985, López-Avila 1986), but others as a transitional stage (Husain 1931, Gill 1990, Bethke et al.1991, Byrne & Bellows 1991). We agree with the latter conclusion and regard its duration time as difficult to delineate, but morphologically distinct. Fourth instar-pupa lasted 5.8 ± 0.3 d being similar to the results of El-Helaly et al. (1971), but different from authors who considered this instar as two separate stages (Azab et al. 1971, López-Avila 1986, Peña-Rojas et al. 1992).

Life Cycle

The duration from egg to adult was 22.3 d, which is very similar to that reported by Eichelkraut & Cardona (1989) on common beans under the same temperature and relative humidity. Bethke et al. (1991) found that total development times were similar, ranging from 23.2 d (poinsettia population reared on poinsettia) to 25.6 d (cotton population reared on poinsettia). Other authors have reported life cycles from 14 to 107 d, depending upon temperature, indicating that at 25-30°C the cycle was shortened (Husain 1931, El-Khidir 1965, Azab et al. 1971, Butler et al. 1983). Coudried et al. (1985) found that the time required for *B. tabaci* to complete the development from egg to adult at 26.7 ± 1°C was influenced by the host plant on which it was fed. For instance, mean duration in days varied among hosts: carrot (29.8), broccoli (29.7), tomato (27.3), pepper (23.4), cantaloupe (22.3), watermelon (22.3), common beans (21.8), cotton (21.7), squash (21.3), aubergine (20.9), cucumber (20.6), lettuce (19.4) and sweetpotato (18.6). Development was completed in 30% less time on lettuce, cucumber, aubergine, and squash than on broccoli or carrot. Based on our results, we suggest that under the tropical conditions of Venezuela, 10 to 16 generations per year may occur, which is similar to reports by Husain (1931), Avidov (1956), and Azab et al. (1971).

Nymphal Instars

Through direct observations, 3 shed nymphal skins were noted indicating that *B. tabaci* has 4 instars on tomato. No shed skins were observed between 4th instar and pupa, only morphological changes. Likewise, Husain (1931) on cotton and López-Avila (1986) on common beans, tobacco, cotton, and tomato reported a 4th instar, but El-Helaly et al. (1971) on sweetpotato and potato and Azab et al. (1971) on sweetpotato reported three instars. Byrne & Bellows (1991) stated that in the literature, whitefly 4th nymphal instar is commonly referred to as a pupa. Bethke et al. (1991) found 4 nymphal instars on different populations of *B. tabaci* reared on poinsettia and cotton leaves. They included 4th instars as a pupal stage. Lynch & Simmons (1993) reported 4 nymphal instars of *B. tabaci* strain B reared on peanut.

Preoviposition and Oviposition

Preoviposition was 1.4 ± 0.7 and ovipositional period 16.7 ± 3.2 d. These results are similar to those reported by López-Avila (1986) and Eichelkraut & Cardona (1989), but differ from Sharaf & Batta (1985) regarding preoviposition. They found a duration of 3.6 and 4.9 d at 25 and 14°C, respectively. The oviposition time we observed was similar to that of Husain & Trehan (1933), and the duration range similar to that of Eichelkraut & Cardona (1989), who stated that oviposition occurred within the first five days.

Fecundity and Viability

The mean number of eggs laid per virgin female was 194.9 ± 59.1 and the mean number per female per day was 11.7 ± 3.6. Azab et al. (1971) and Gameel (1974) reported an average of 161 eggs per female on sweetpotato and cotton, respectively. Avidov (1956) pointed out that 300 or more eggs were oviposited per female, however, other researchers found a much lower number, indicating the influence of the temperature on fecundity (Husain 1931, Husain & Trehan 1933, El-Khidir 1965, Butler et al. 1983, Sharaf & Batta 1985,Eichelkraut & Cardona 1989). Among 104 eggs observed, 86.5% hatched. Butler et al. (1983) reported a hatchability of 68 and 75% at 26.7 and 32.2°C, respectively.

Sex Ratio and Parthenogenesis

Among 220 dissected adult genitalia, 161 showed female structural parts, whereas 59 were male, resulting in a ratio of 1: 2.7 (male: female). These results are similar to those of López-Avila (1986) at the same temperature and agree with the statement of

Azab et al. (1971) that females are more numerous than males. However, our results differ from those of Sharaf & Batta (1985) who reported sex ratios of 1:1.8 and 1:3.1 (male:female) when temperature decreased from 25 to 14°C, increasing the number of females. Eichelkraut & Cardona (1989) found a sex ratio of 1:1 (n:600). Only males hatched from eggs laid by virgin females suggesting that the parthenogenesis observed was of the arrhenotoky type. These results are similar to others authors (Husain & Trehan 1933, Mound 1983, Sharaf & Batta 1985, Eichelkraut & Cardona 1989).

Acknowledgments

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THE FRESHWATER MACROINVERTEBRATES OF FLORIDA: A GUIDE TO REFERENCES FOR THEIR IDENTIFICATION

MICHAEL D. HUBBARD, MANUEL L. PESCADOR, ANDREW K. RASMUSSEN,
INGOLF S. ASKEVOLD, JEROME JONES, R. WILLS FLOWERS, AND JOHN H. EPLER
Entomology, Center for Water Quality, Florida A&M University,
Tallahassee, FL 32307

ABSTRACT

A list of identification guides is presented, including keys, descriptions, and other information, many with attached annotations. We have found these manuscripts useful in the determination of the freshwater macroinvertebrates of Florida.

Key Words: Keys, macroinvertebrates, aquatic, freshwater, Florida fauna

RESUMEN

Es presentada una lista de guías de identificación que incluye claves, descripciones y otras informaciones, muchas con anotaciones adjuntas, que son útiles para la determinación de macroinvertebrados de agua dulce de la Florida.

Identification of the freshwater macroinvertebrate fauna of many areas is often a difficult process. Florida is certainly no exception. For most groups there are no comprehensive keys to the Florida fauna and other useful keys are usually scattered and hard to find for the non-specialist.

This paper contains a list of publications and keys, many annotated, which we have found useful for identifying the freshwater macroinvertebrates of Florida. It is an attempt to make these references more available to researchers who need to identify the freshwater macroinvertebrates of Florida. Some of the groups of Florida freshwater macroinvertebrates are not well known and this is reflected in the lack of adequate literature for identifying these groups.

The number of papers listed for the different groups varies widely. This is related to, among other factors, the number of species present in Florida, the difficulty in actually determining the identity of these species, and the recency and availability of comprehensive revisions of the various taxa.

We have tried to include all taxa of truly aquatic macroinvertebrates; i.e., those with at least one aquatic life history stage. We have also included some semiaquatic taxa which are likely to be found in aquatic collections.

In order to facilitate use, taxa in this paper are arranged alphabetically within groups, starting with phyla and working down the taxonomic hierarchy.

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[Contains keys, description, and discussions for 35 species of *Arrenurus*]

COOK, D. R. 1976. North American species of the genus *Koenikea* (Acarina: Unionicolidae). Contributions of the American Entomol. Institute 11(4):59-100. [Contains keys, description, and discussions for 20 species of *Koenikea*, many from Florida]

COOK, D. R. 1976. North American species of the genus *Mideopsis* (Acarina: Mideopsidae). Contributions of the American Entomol. Institute 11(4):101-148.
[Contains keys, description, and discussions for 25 species of *Mideopsis*, many from Florida]

PLUCHINO, E. S. 1984. Guide to the common water mite genera of Florida. Florida Dept. of Environmental Regulation Tech. Series 7(1): 45 pp.
[Contains key to common Florida genera; includes basic biological information]

INSECTA (COLEOPTERA: GENERAL)

ARNETT, R. H. 1963. The beetles of the United States. Catholic Univ. of America Press, Washington, D.C. xi + 1112 pp.
[Includes keys to families, subfamilies and genera of the beetles of North America north of the Rio Grande, with brief notes about numbers of species for each genus. It is now extremely out of date, and was fraught with numerous difficulties when first published; many of the keys do not work]

BRIGHAM, W. U. 1982. Aquatic Coleoptera. Pp 10.1-10.136 *In* A.R. Brigham, W.U. Brigham, and A. Gnilka, (eds.), Aquatic insects and oligochaetes of North and South Carolina. Midwest Aquatic Enterprises, Mahomet, Illinois.
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[Includes figures and keys to genera of beetles; while geared specifically to that region, most of the genera are common to Florida, and it is far better illustrated than Arnett, 1963]

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[An illustrated expert system for the identification of larvae of Coleoptera to family and subfamily; requires CD ROM system]

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[Nice volume but quite out of date; includes all the "water beetles", strictly speaking, the Dytiscidae, etc., and certain non-Adephaga families: Hydrophilidae, Hydraenidae, Dryopidae and Elmidae; Hydrochidae were separated from the Hydrophilidae]

INSECTA (COLEOPTERA: CHELONARIIDAE)

ARNETT, R. H. 1963. The beetles of the United States. Catholic Univ. of America Press, Washington, D.C.

INSECTA (COLEOPTERA: CHRYSOMELIDAE)

[A number of subfamilies include somewhat aquatic species, such as the flea beetle *Agasicles* that has been introduced on alligator weed, and *Mantura* that is often collected in roadside ditches. However, only the Donaciinae are entirely aquatic]

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ASKEVOLD, I. S. 1991b. An annotated list of Nearctic Donaciinae (Coleoptera: Chrysomelidae): the generic classification and type specimens of the New World species. Psyche 98:165-192.

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[includes keys to subfamilies and many of the species that occur in Florida]

MARX, E. J. F. 1957. A Review of the subgenus *Donacia* in the Western Hemisphere (Coleoptera: Donaciidae). Bull. of the American Museum of Natural History 112:191-278.

[Key to species, distributional and host data for species of what is now restricted to *Donacia* (*Donacia*) and *Donacia* (*Donaciomima*); keys work fairly well, and taxonomy can be updated using Askevold, l991b)

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[includes a few genera that often occur in semiaquatic habitats]

WILCOX, J. A. 1975. Checklist of the beetles of North and Central America and the West Indies. Volume 8, fam. 129, Chrysomelidae. Flora and Fauna Publ., Gainesville, Florida 166 pp.

[Assists in correct taxonomic placement of species to genus, but provides no references or aids to identification]

INSECTA (COLEOPTERA: CURCULIONIDAE)

[There are many genera and species of aquatic weevils, and they are very difficult to identify. Most genera are poorly studied, with numerous undescribed species, even from Florida alone. There are also a number of aquatic weevils introduced as biocontrol agents, and these are not covered by most available literature]

BLATCHLEY, W. S AND C. W. LENG. 1916. Rhynchophora or weevils of north eastern North America. Nature Publ. Co., Indianapolis. 682 pp.
[Very out of date, but some of the keys and descriptions are useful; taxonomy needs to be carefully traced using O'Brien & Wibmer, 1982; many of the aquatic weevils of Florida are treated]

BOARD, V. V. 1972. Taxonomy and biology of *Endalus* Laporte and *Onychylis* LeConte in America north of Mexico. Ph.D. Thesis, Texas A&M Univ., College Stn., TX.
[*Endalus* is no longer valid; *Notiodes* Schönherr is the valid name].

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[The only published key to all genera of North American weevils; some taXonomy out of date]

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O'BRIEN, C. W., AND G. B. MARSHALL. 1979. U.S. *Bagous*, bionomic notes, a new species, and a new name (Bagoini, Erirhininae, Curculionidae, Coleoptera). Southwestern Entomol. 4(2):141-149.

O'BRIEN, C. W., AND G. J. WIBMER. 1982. Annotated checklist of the weevils (Curculionidae *sensu lato*) of North America, Central America, and the West Indies (Coleoptera: Curculionoidea). Memoirs of the American Entomol. Institute Volume 34 ix + pp 1-382.
[An essential reference to trace taxonomy, identifications and distributions, from older literature]

TANNER, V. M. 1943. A study of the subtribe Hydronomi with description of new species, (Curculionidae) study No. VI. Great Basin Naturalist 4(12):1-38.
[Outdated, keys difficult to use; many species in Florida, distribution poorly known; keys genera of most aquatic weevils, treated as a single group, but this is a polyphyletic assemblage; contains a number of very good and accurate habitus illustrations, however]

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[Keys work with most Florida species]

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[Most complete treatment of adult Pyralidae available; excellent application to Florida fauna]

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[Good key to Carolina larvae; includes most Florida species that range northward into Carolinas]

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DAMAGE TO WATERMELON SEEDLINGS CAUSED BY *FRANKLINIELLA FUSCA* (THYSANOPTERA: THRIPIDAE)

SUSAN E. WEBB
Central Florida Research and Education Center
University of Florida
5336 University Avenue, Leesburg, FL 34748

The spring watermelon [*Citrullus lanatus* (Thunb.) Matsum & Nakai] crop in North Central Florida does not normally suffer much direct feeding damage from insects. For the past five years, however, many young plants have been found with scarred and distorted leaves. The most heavily damaged plants appeared to be stunted as well. Thrips were found on seedlings, and an experiment was performed to determine if the observed damage was caused by their feeding.

Watermelon seedlings showing typical damage, thinned from a 2-ha field at the Central Florida Research and Education Center, were chilled and then searched for thrips. Thrips were collected by aspirating into medicine droppers; 30 to 40 were sealed into individual droppers with Parafilm. Thrips were then released onto watermelon seedlings ('Charlee'), most having two true leaves, planted in groups of eight to 10 in five 12-liter pots. Plants were covered with cast acrylic cylinders that fit inside the pot rim, the open end covered with nylon organdy. Plants were placed in an insect rearing room kept at $23 \pm 2°C$ with a photoperiod of 16: 8 (L:D). Some thrips were preserved in 70% ethanol for identification. Plants were observed as they grew, and photographs were taken at intervals to record damage.

Damage produced by thrips was identical to that found in the field (Fig. 1). Plants without thrips remained symptomless. Damage to infested plants (silvery, clear areas on leaves, crinkling, and chlorotic spots and streaks) became apparent as each new leaf expanded, suggesting that feeding was occurring mainly in the terminal buds. Some minor feeding damage also occurred on the upper surface of cotyledons and on already-expanded leaves. Thrips used to infest plants were identified as *Frankliniella fusca* (Hinds), the tobacco thrips. Recently, this same thrips was identified from badly damaged watermelon seedlings growing in a greenhouse at the Central Florida Research and Education Center.

F. fusca is a polyphagous species that has been reported to cause direct damage to peanuts and cotton (Newsom et al. 1953, Watson 1965, Morgan et al. 1970), in addition to vectoring tomato spotted wilt virus (Sakimura 1963). In peanuts, damage results from feeding on the epidermis of unopened leaflets, giving rise to scarred and deformed leaves (Morgan et al. 1970). No increase in yield could be attributed to controlling thrips populations, however. Variable results have been obtained in cotton, ranging from no noticeable differences in yield (Watson 1965), to some yield loss in cotton grown on dry, sandy hills (Newsom et al. 1953). Newsom et al. (1953) concluded that, in general, the only advantage gained from control of thrips was more uniform and vigorous growth in the first 4 to 6 wk.

In commercial fields and in our research plots, leaf damage became less apparent and eventually ceased after plants entered a period of rapid growth. Thrips injury in cotton is outgrown in 4 to 6 wk (Watson 1965). It is not known if thrips populations decline naturally, or if the rapid growth of susceptible tissue limits the amount of feeding that can occur during the time that terminal buds of watermelon are a suitable habitat for thrips. Studies to assess the effects of controlling early thrips infestations may be worthwhile.

Fig. 1. Watermelon seedling showing damage due to feeding of *F. fusca*. Thrips were added to caged plants when seedlings had two true leaves.

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SUMMARY

Damage to spring-planted watermelon seedlings was reproduced under controlled conditions by infesting plants with field-collected tobacco thrips, *Frankliniella fusca* (Hinds). Under field conditions, plants appeared to recover as growth rate increased.

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A PREVIOUSLY UNKNOWN SEXUAL CHARACTER FOR THE PEPPER WEEVIL (COLEOPTERA: CURCULIONIDAE)

FRED J. ELLER
Bioactive Constituents Research
National Center for Agricultural Utilization Research
USDA/ARS/MWA 1815 N. University Street
Peoria, IL 61604

The pepper weevil, *Anthonomus eugenii* Cano (Coleoptera: Curculionidae), is an important pest of both sweet and hot peppers (*Capsicum* spp.) in the southern United States, Mexico and Central America (Elmore et al., 1934). Eller et al., (1994) describe the isolation, identification, and field activity of a male-produced pepper weevil aggregation pheromone. During investigations of the aggregation pheromone of the pepper weevil, it was necessary to sex individuals to identify male-specific chemicals. In addition, weevils captured during field trials of synthetic pheromones were sexed to determine whether the pheromone attracted both sexes. Pepper weevils can be sexed by examination of the eighth tergum using characters described for sexing the boll weevil (Coudriet & Kishaba, 1988) (males have a notch in the eighth tergum, see Figure 1). However, the tergum is often not exposed, especially in weevils captured in pheromone traps. Dietz (1891) reported that female pepper weevils have a more slender and less densely punctured rostrum than males and their antennae are inserted further from the mouthparts. Although these sexual dimorphisms generally hold, these characters are somewhat subjective and are not completely reliable (Patrock, 1986). Some anthonomines can be sexed by examination of the tarsal claws (Kovarik & Burke, 1983), however, Patrock (1986) reported there is no sexual dimorphism of the tarsal claws of pepper weevils. The objective of this study was to find an obvious and reliable sexual dimorphism for sexing pepper weevils.

A laboratory culture of pepper weevils was established from insects collected in Florida and reared according to methods described by Patrock (1986). Pepper weevils were examined using a Nikon SMX-2B stereomicroscope and it was found that males (sexed by examination of genitalia) possess metatibial mucrones (Figures 1 and 2A). These metatibial mucrones are visible at magnifications of about 80×. In males, the mucrones of the protibia and mesotibia are not curved and are much shorter and thinner than the metatibial mucrones. Scanning electron micrographs were taken using a JEOL JSM-6400V scanning microscope. The electron micrographs revealed the inner surface of the mucrones of males to be coarse and scale-like. Although females also possess metatibial mucrones, they are not curved and they are much shorter and more slender than those of males (Figure 2B). The metatibial mucrones of females are about the same size as the mucrones of the protibia and mesotibia. The surface of female mucrones were not obviously scale-like. The metatibia of males tends to be more strongly curved than those of females, however, this character is not as reliable as the metatibial mucrones.

I found this method of sexing pepper weevils to be very useful for determining the sex of pepper weevils used in laboratory experiments and those captured in field trials. Although the function of the metatibial mucrones is unknown, I hypothesize that they are used by the male to grasp the female during mating. Sexual dimorphism of tarsal claws in other anthonomines is thought to be another adaptation for grasping the female during copulation (Kovarik & Burke, 1983).

Several other species of *Anthonomus* were examined to determine if this character could be used to sex them as well. The species examined included: the boll weevil, *A.*

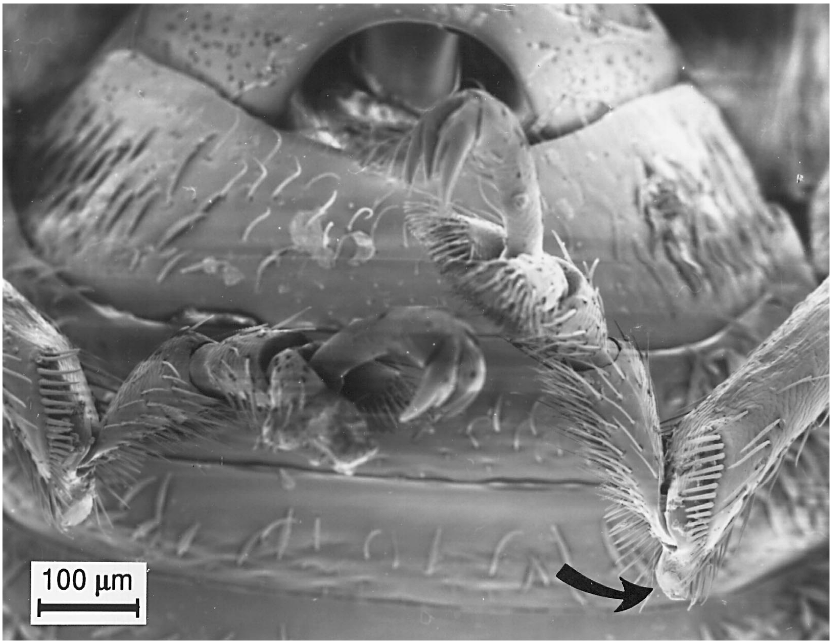

Fig. 1. Ventral view of male pepper weevil. Arrow indicates location of metatibial mucro.

grandis Boheman; the cranberry weevil, *A. musculus* Say; the potato bud weevil, *A. nigrinis* Boheman; the apple curculio, *A. quadrigibbus* (Say); the strawberry bud weevil, *A. signatus* Say; *A. texanus* Dietz; *A. albopilosus* Dietz; and *A. aeneolus* Dietz. Of these species, only *A. texanus* is clearly dimorphic in the metatibial mucro character. Male *A. texanus* have larger mucrones than females.

I wish to thank David G. Riley for providing a start-up culture of pepper weevils. Scanning electron micrographs were prepared by Lee Baker. Technical assistance was provided by Betty Thomas, Bruce Zilkowski and JoAnne Toohill. Horace R. Burke and Wendy Mechaber supplied other species of *Anthonomus* for examination. The author wishes to thank Drs. Horace R. Burke, Patrick F. Dowd, and David R. Schuster for reviewing an earlier draft of this manuscript.

Summary

Male pepper weevils possess metatibial mucrones which are larger and more strongly curved than those of females. This secondary sexual character is an easy and reliable method for sexing pepper weevils.

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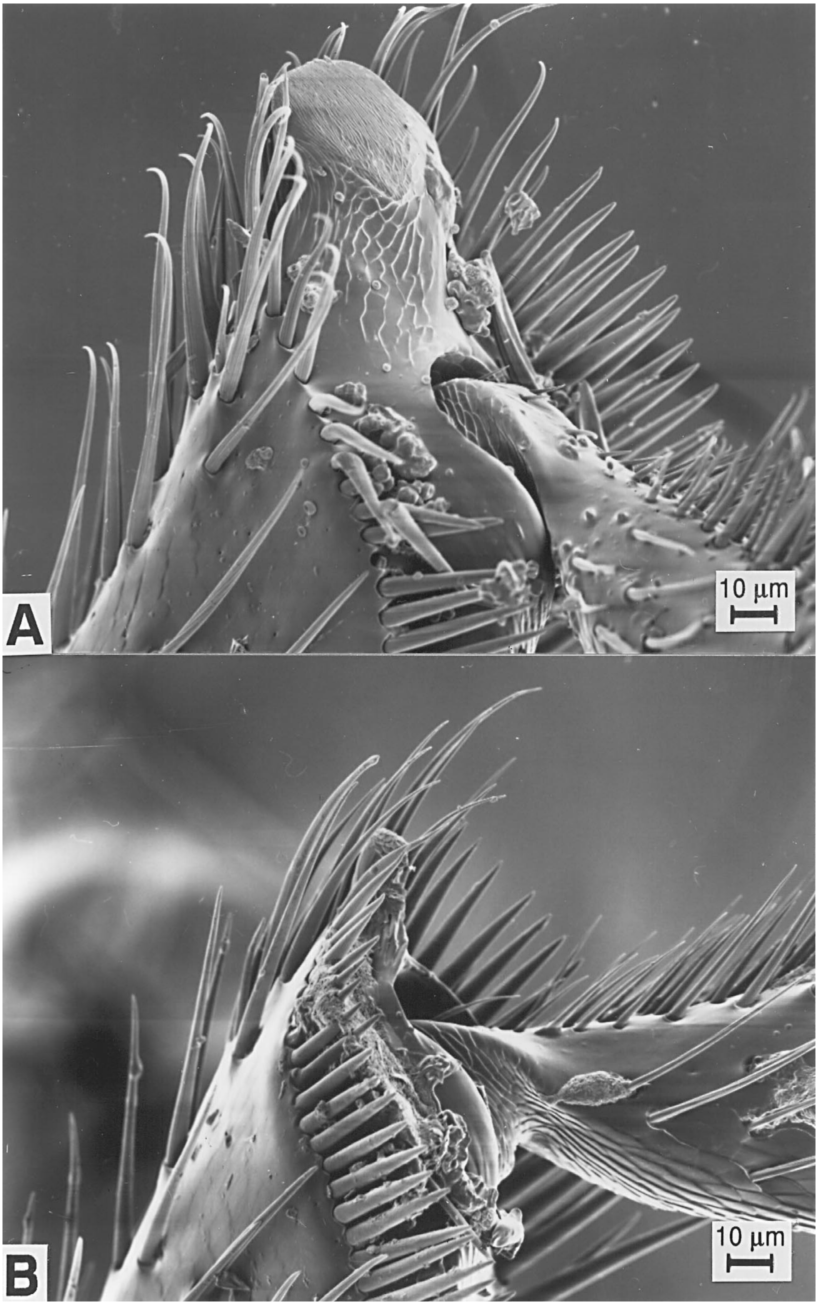

Fig. 2. Lateral view of apex of metatibia showing mucrones of male (A) and female (B) pepper weevils.

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CITRUS LEAFMINER (*LEPIDOPTERA:GRACILLARIIDAE*) ON FRUIT IN FLORIDA

J. B. HEPPNER
Florida State Collection of Arthropods, Division of Plant Industry,
Florida Dept. of Agriculture & Consumer Services,
Gainesville, FL 32614-7100

The citrus leafminer, *Phyllocnistis citrella* Stainton (Gracillariidae: subfamily Phyllocnistinae) (CLM), was found in late May 1993 in several citrus nurseries in Homestead, Florida (Dade Co.). It is a major citrus pest in the Old World, causing extensive damage to new leaf flush, particularly on nursery citrus stock. Originating in southeast Asia, CLM occurs in Australia, Japan, Taiwan, the Middle East to Sudan, South Africa, and parts of coastal West Africa. Previous reports have summarized our current knowledge of CLM (Heppner, 1993a, 1993b). The current distribution of CLM in Florida is summarized in Fig. 1.

Infestations in Florida of CLM have resulted in occasional reports of fruit damage by miners to the fruit rind. Invariably, these and older reports, even prior to CLM arrival, have been the result of damage from another miner, *Marmara* n. sp. (Gracillariidae) which is known to occur in Florida. It is possibly the same species which occurs in California (Davis, Smithsonian Institution, Washington, DC; pers. comm.). A few fruits have been found in the past year with fruit mines very much like the serpentine traces of CLM on leaves. *Marmara* miners have more open larval tracks.

Recent collections of fruit samples from Vero Beach, Indian River Co., by R. C. Bullock (IFAS, Ft. Pierce, FL), resulted in the isolation of larvae from the CLM-appearing mines of fruit (Fig. 2-3). Confirmation of the species involved a comparison of larvae of *Marmara* n. sp. (Fig. 4) and CLM which clearly showed that the serpentine mines on fruit are the result of CLM damage. Until now, no report has been made of CLM attacking citrus fruit in the Old World, although injury to new branch growth has been known and reported.

CLM literature is extensive for its home range, from India to China and Indonesia (Heppner, 1993b), but none of these papers report damage to fruit.

Florida fruit damage records can now be confirmed for CLM for the following suspected records (all are on young fruit):

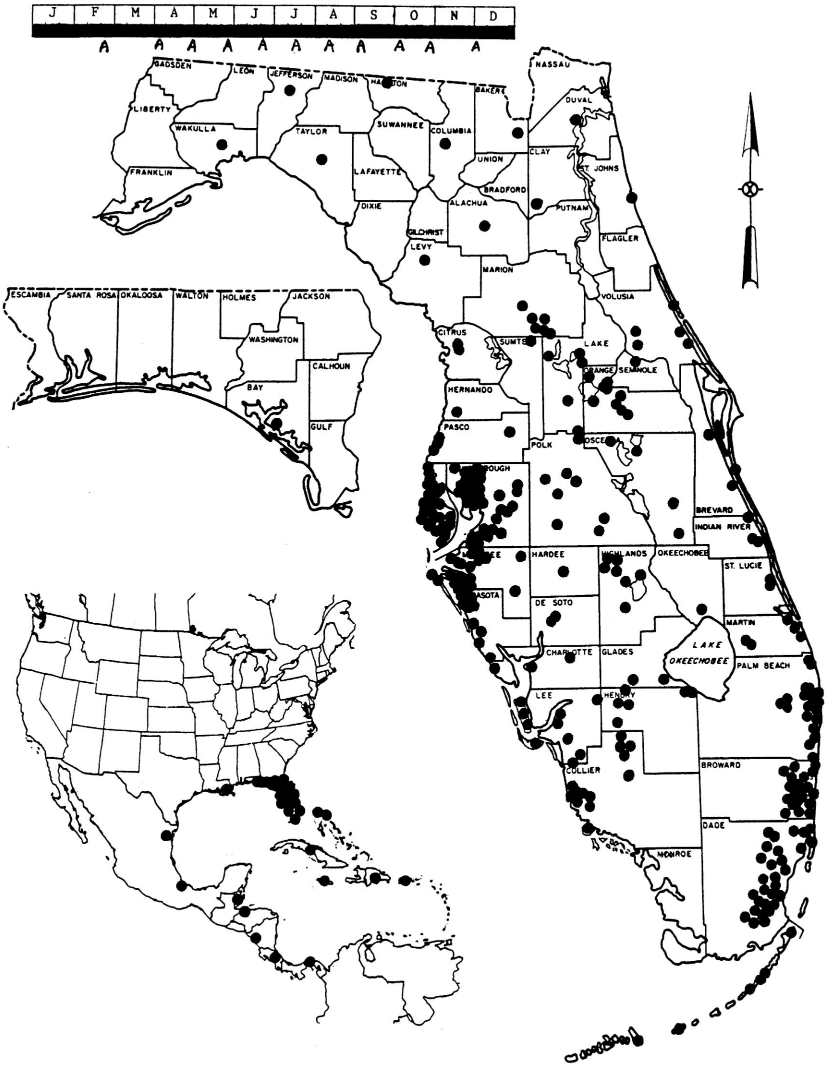


Fig. 1. Distribution map of CLM in Florida and the Caribbean as of May 20, 1994.

MANATEE CO.

Parrish: 23 September 1993, on grapefruit

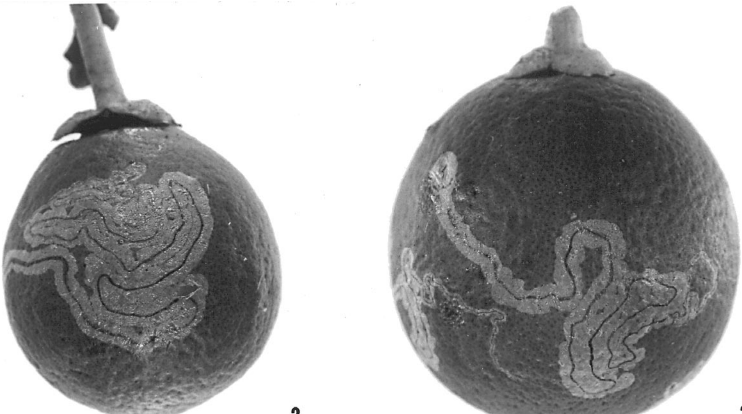
Bradenton: 23 September 1993, on grapefruit

— 29 September 1993, on grapefruit

— 28 April 1994, on pummelo

Palmetto: 28 October 1993, on red grapefruit

Ellenton: 10 May 1994, on ruby grapefruit



2 3

Fig. 2-3. Fruit damage from CLM: samples from Vero Beach, Indian River Co., Fla., 20 Apr 1993, R. C. Bullock. (photographs by J. Lotz, FDACS, DPI).

4

Fig. 4. Fruit damage from *Marmara* n. sp.: samples from Manatee Co., Fla., 1993. (photograph by J. Lotz, FDACS, DPI)

INDIAN RIVER CO.

Vero Beach: 20 April 1994, on grapefruit

Also, suspected samples had been found in the Bahamas (Abaco Island) on fruit during 1993 (courtesy of R. Nguyen), which undoubtedly are CLM.

It appears that in cases of massive infestations CLM attacks even young fruit. Another possibility for the lack of fruit mining by CLM in other countries can be the fewer varieties of citrus being grown there, since in Florida numerous varieties are grown and some of these may be more susceptible to CLM attack. Fruit damage in Florida from CLM also has been restricted to grapefruit (the Bahamas record is *Citrus* sp., unspecified as to variety).

The efforts of R. C. Bullock (University of Florida, IFAS Agricultural Experiment Station, Ft. Pierce, Florida), and W. N. Dixon and R. Nguyen (FDACS, DPI, Gainesville, Florida), in obtaining fruit samples with miners are appreciated. The many plant protection specialists of the Florida Dept. of Agriculture and Consumer Services, Division of Plant Industry, are thanked for their extensive search for fruit miners. Contribution No. 795, Section of Entomology, DPI, FDACS.

SUMMARY

The first report of citrus leafminer, *Phyllocnistis citrella*, damaging grapefruit in Florida, was confirmed for Manatee and Indian River Counties.

LITERATURE CITED

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VELVETBEAN CATERPILLAR (LEPIDOPTERA: NOCTUIDAE): SURVIVING FREEZING WEATHER IN LOUISIANA

XIKUI WEI[1] AND SETH J. JOHNSON
Department of Entomology, Louisiana Agricultural Experiment Station,
Louisiana State University Agricultural Center,
Baton Rouge, LA 70803

The velvetbean caterpillar (VBC), *Anticarsia gemmatalis* Hübner, (Lepidoptera: Noctuidae) is predominately a tropical to subtropical species (Buschman et al. 1977, 1981) and cannot overwinter north of southern Florida (Ellisor 1938, Buschman et al. 1977) and southern Texas (Gregory et al. 1990). However, adults are collected as far north as Ontario, Canada (Watson 1916) by late summer. VBC is a yearly immigrant to Louisiana and other soybean growing areas in the southeastern U. S. (Johnson et al. 1991) and can be a severe pest if not controlled.

There has been considerable discussion about the factor(s) limiting the VBC's northern overwintering range. Several limiting factors have been suggested including: host plant availability (Anonymous 1927; Watson 1932), absence of a mechanism of winter dormancy (Anonymous 1927), or direct exposure to sublethal temperatures (Buschman et al. 1977). Near the VBC's normal northern overwintering boundary in Central Florida (Bartow, FL) larvae of all sizes have been collected throughout the winter on a wild host plant, kudzu *Pueraria lobata* (Willd.), even though the host plant was nearly defoliated; however, this was an area with no freezing temperatures (Buschman et al. 1977). Using both laboratory and field cage experiments in Mississippi, Buschman et al. (1981) investigated the overwintering ability of the VBC and

[1]Current address: Texas A&M University, Research & Extension Center, 17360 Coit Road, Dallas, TX 75252.

concluded that it did not survive the winter of 1978-79, which was regarded to be severe in that area. They collected the last VBC larvae on kudzu on December 6 at Hillsdale (southern Mississippi) after the kudzu foliage at Hillsdale was killed by freezing temperatures on December 5, 1978.

In this note, we provide evidence that the VBC can withstand subfreezing temperatures in Louisiana. In our study, we set up two cages (1.8 x 1.8 x 1.8 m) in a soybean field at Ben Hur Experiment Station, Louisiana State University Agricultural Center, Baton Rouge on October 9, 1993. The ground inside the cages was covered with nylon screen and a layer of vermiculite about 2 cm was placed on the screen. Vermiculite was used to facilitate pupal collection (see also Wei & Johnson 1994). Approximately 200 VBC third and fourth instars were collected from adjacent soybean fields with a sweep-net and introduced into each cage. AMDRO® (American Cyanamid Company, Wayne, NJ) insecticide was applied around the cages to prevent fire ants from attacking the insects in the cages. On October 31, 1993, three weeks after larval introduction, the temperature dropped to - 2.3°C and was below 0°C for 9 hrs. This was preceded by 134 mm of rain on October 29, 1993 which caused water to stand in the cages for more than 48 hrs. Observations at the cage sites and in the adjacent soybean field were made on the evenings of November 8th, 12th, and 14th, 1993. All soybean plants at the farm had senesced and died due to three freezes (ranging from -1 to -2.3°C) that occurred from October 31 to November 7, 1993. However, on each sample date we observed many VBC moths feeding on the ergot-infested spikes of Dallis grass, *Paspalum dilatatum* Poiretat, which had not totally senesced (Fig. 1). On November 8th over 60 moths were observed in the fields.

Sampling for VBC was conducted on November 8, 1993 (four weeks after larval introduction) and we found that many larvae had pupated in the vermiculite. A total of 126 pupae, 13 larvae/prepupae and 10 adults were recovered from the two cages. We returned the larvae and pupae to the laboratory and recorded 61 percent moth emergence over the next 12 days. This indicates that VBC larvae, pupae, and adults can survive freezing weather during October and November; however, the soybean host plant did not survive the freezing conditions.

Results of the study reported here indicate that timing of the first killing freeze for host plants may determine the limit of the VBC's temporal distribution. It is likely that VBC larvae die from starvation after host plants are killed. Results from a four year population ecology study on the wild legumes in Plaquemines Parish, the most southern parish in Louisiana, support this same conclusion. In this study VBC larvae were not collected after host plants were killed by freeze; however, the last month in which larvae were collected showed considerable variation among years: (January 1986-87 and 1987-88; February 1988-89; December 1989-90) (unpublished data S. J. Johnson, B. M. Gregory, Jr. and A. M. Hammond, Jr.). Also, it is not expected that many VBC moths could fly south after November because of the extremely short duration of prevailing winds in this direction with temperatures above flight threshold. Therefore, VBC populations present in Louisiana after November would likely not survive.

We would like to thank Zhuofei Song for her assistance in field observations and taking the photograph. Approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript number 94-17-8237.

SUMMARY

This note documents that the velvetbean caterpillar can survive freezing weather (-1 to - 2.3°C) in Louisiana. This finding suggests that the low lethal temperature limit for the VBC is lower than that for its host plants. Therefore, in Louisiana and

probably in areas near its overwintering boundary, availability of suitable host plants for VBC may be more important than cold temperature in limiting the ability of this insect to overwinter.

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Fig. 1 Velvetbean caterpillar moth feeding on honeydew from ergot-infected seed head of Dallis grass

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BOOK REVIEW

GAGNÉ, R. G. 1994. The gall midges of the Neotropical region. Comstock Publishing Associates (Division of Cornell Univ. Press), Ithaca, New York. xiv + 352 p. ISBN 0-8014-2786-X. Hardback. $54.50.

This is the second of a two-part series in which the author has taken a highly esoteric and nearly intractable subject, the systematics of gall midges, and made it useful, accessible and interesting to both the taxonomic and plant science communities. From the perspectives of diversity and taxonomy, the gall midge family, Cecidomyiidae, is of interest because it may be the largest of the dipteran families. From an economic viewpoint, it's of interest for its well-known pests such as Hessian fly and sorghum midge and a slew of lesser-known horticultural pests. For simplicity we can speak of Cecidomyiidae as "gall midges," even though many species are not even associated with vascular plants; and we can speak of the damage they cause to plants as "galls" even though manifestation may be in much less obvious forms such as stem, vein or root swellings, leaf curls or blisters, or aborted flowers. Anyone who has ever traipsed through forests, gardens or plant nurseries with an eye to the plants has seen the work of gall midges. Few may have recognized the damage as such, and, prior to access to these books, many fewer still would have attempted an identification.

As the author considers this book to be a companion volume to his 1989 Plant-Feeding Gall Midges of North America, a comparison of the two is in order. First and foremost, it was the author's obvious intention with both books to make it possible for even a layman to associate visible plant damage or deformity with a known causative agent. Secondly, he set out to synthesize and clarify the taxonomy of a difficult and poorly studied group. Both books are extremely effective in attaining these objectives for their stated areas of coverage.

The organization and formatting of the two books are nearly identical. By necessity there is overlap in subject coverage of several introductory chapters, e.g. those on biology, anatomy, and collection and preparation techniques. However, the Neotropical volume treats Cecidomyiidae more broadly to also include non-plant feeding midges. Extreme southern Florida is included in the neotropical coverage, as so much of the flora there is shared with that of the West Indies. I was surprised at the relative slimness of the present book; in fact it is a few pages shorter than the North American version. Every named cecidomyiid known to occur in the Neotropics, about 450 species in total, is treated here. In contrast, over 1,200 named species comprise the North American fauna, and Gagné's 1989 book records those 900 species directly associated with plants. Obviously, only a small fraction of Neotropical species has been discovered, and, in Gagné's words, the actual number of species there is "inestimable."

Two chapters comprise the heart of the book. One is a taxonomic synopsis of Neotropical Cedidomyiidae, neatly broken down into its various levels such as subfamily, tribe, and genus. A morphological diagnosis and an accounting of biology, numbers of species, and worldwide distribution is provided for each higher taxonomic category in a thorough but succinct manner. Further, each of the 453 named species is completely catalogued with information on its original citation, type specimens, synonymy, geographical distribution and useful references. Several dichotomous keys to adult identification are included for groups where knowledge is sufficient to warrant a key. Members of the largest subfamily, Cecidomyiinae, are keyed mostly to genus level. Two genera and three species are newly described, and scores of nomenclatural changes are included.

The second major chapter consists of a series of keys to cecidomyiids based on the plant damage they cause. The keys are arranged alphabetically by plant family and genus. If one can identify the host plant, it is a very simple matter to arrive at an identification of the cecidomyiid causing the damage. Because of our very limited knowledge of Neotropical cecidomyiids, most plant genera listed here are known hosts to only a single midge species. And it is very often the case that the given damage can be attributed only to "cecidomyiid," further identification being impossible. Based on the host genera included in the keys, descriptions of galls and associated illustrations, one can know in an instant whether a gall in question and the midges causing it are known to science.

One clear message conveyed by this book is how little we know on the subject of Cecidomyiidae and the Neotropics. This is reflected in a short first chapter, in which Gagné recounts the abbreviated biographies of 11 individuals most prominent in bringing Neotropical cecidomyiid taxonomy to light. A little reading between the lines reveals huge gaps in the geographical coverage of their studies. The few steps taken to date have been large and significant, but there remains ahead of us a long journey of discovery. Gagné's book is more than another step, however. It is a bridge to a clearer, straighter course, and progress will be much the quicker for it.

Gary J. Steck
Division of Plant Industry
Florida Department of Agriculture &
Consumer Services
Gainesville, FL 32614-7100

IN MEMORIAM

WILLIS WAGNER WIRTH

Willis Wagner "Bill" Wirth, renowned biting midge specialist, died on 3 September 1994 in Gainesville, FL. Wirth was born 17 October 1916 on a farm near Dunbar, NE. He majored in biology at Peru (Nebraska) State Teachers College (1933--1938). He received a B.S. degree in zoology and entomology from Iowa State University in 1940, an M.S. in entomology from Louisiana State University in 1947, and a Ph.D. in systematic entomology from the University of California at Berkeley in 1950.

During World War II, Wirth served as a commissioned officer in the U.S. Public Health Service. He was assigned to malaria control in Louisiana and to quarantine service in Miami and Honolulu. While in Honolulu, his survey work revealed that the oriental fruit fly and other insects from Asia and the western Pacific had become established in Hawaii.

From 1947 to 1949, he was a teaching assistant in insect systematics and forest entomology at the University of California at Berkeley. During the summers of 1947 and 1948, Wirth worked on mosquito surveys for the California Department of Health, with special reference to encephalitis virus isolations.

From 1949 to 1983, Wirth was a research entomologist for USDA-ARS at the National Museum of Natural History, Smithsonian Institution, in Washington, DC. Wirth's research assignments included taxonomic studies on Diptera, particularly the biting midges of the family Ceratopogonidae. He received several USDA citations for superior work performance. In 1956, he was a Fulbright Research Scholar at the School of Public Health, University of Sydney, Australia, working on the biology and taxonomy of Australian biting midges. He also served in many special assignments while employed by USDA. These assignments included work at the University of Florida in 1951 (to study biting midges), the U.S. Livestock Insects Research Laboratory (Kerrville, TX) in 1953 and 1955, various European museums (to study type collections of early taxonomists) in 1957, the New York State Museum in 1961, a Smithsonian-Archbold-Bredin Biological survey of Dominica in 1965, Panama (to study the breeding places of Neotropical biting midges) in 1967, and Great Plains (to study biting midges and brine flies) in 1969. His accomplishments included more than 400 scientific publications, mostly in public health and the taxonomy of Ephydridae, Chironomidae, Canaceidae, Dolichopodidae, and especially Ceratopogonidae. He was widely recognized as the world's foremost authority on Ceratopogonidae.

Wirth was a Life Member and Fellow of the Entomological Society of America, having served on the Editorial Board, Thomas Say Foundation (1960-1964), and as secretary of Section A in 1960. He was also a member of the Entomological Society of Washington, Pacific Coast Entomological Society, Hawaiian Entomological Society, Florida Entomological Society, Kansas Entomological Society, Association for Tropical Biology, Biological Society of Washington, Washington Biologists' Field Club, and Society for Systematic Zoology. He was an adjunct professor of entomology at the University of Maryland and the University of Florida and a research associate of the Florida State Collection of Arthropods.

After retiring in 1984, Wirth moved to Gainesville, FL. There, he continued entomological research as a research associate of the Florida Department of Plant Industry. He remained active in entomology by presenting papers at meetings, submitting articles for scientific publication, serving on graduate student committees, and sharing his knowledge, experience, and insect collection with others. He was a friendly, kind, and generous person who will be greatly missed by all that knew him. As a scientist, he was an inspiration and a role model for others. His contributions to science will endure for many years to come.

Dr. Wirth's survivors include his wife, Mabel, of Gainesville; a son, William Frederick Wirth of Sullivan, WI; a daughter, Katherine Jarvis of Rock Cave, WV; two stepsons, Stephen Petranek of Chappaqua, NY, and Gary Petranek of Silver Spring, MD; a stepdaughter, Kathleen Moody of New Port Richey, FL; a brother, Arlow Wirth of Hartington, NE; a sister, Lois Davia of Homewood, IL; four grandchildren; and three step-grandchildren.

Gary A. Mount
Daniel L. Kline
Gainesville, FL

Daniel V. Hagan
Statesboro, GA

William Grogan
Salisbury, MD

THE HISTORY OF THE BUREAU OF ENTOMOLOGY, DIVISION OF PLANT INDUSTRY, FLORIDA DEPARTMENT OF AGRICULTURE AND CONSUMER SERVICES[1]

1 June 1915 to 31 August 1993

HAROLD A. DENMARK
Entomologist Emeritus, Entomology Section, Division of Plant Industry,
Florida Department of Agriculture and Consumer Services, P.O. Box 147100,
Gainesville, FL 32614-7100

INTRODUCTION

A brief history of the State Plant Board (SPB) (now the Division of Plant Industry, DPI) is presented as it relates to the Entomology Bureau from its inception in 1915 until the retirement of the author in 1992, when Entomology, Pathology, and Nematology Bureaus were combined under one Chief. This is followed by a listing of the professional Entomologists who have served over the 80-year history of the Bureau with the dates of their employment, if known, and the highlights of their activities.

The SPB was created with the Legislature's approval of The Plant Act (Chapter 6885 of the Statutes of Florida 30 May 1915). This act provided that the SPB should consist of 5 members, being the same persons who constituted the Board of Control for the University of Florida. At the first meeting on 4 April 1915, Mr. P. K. Yonge was elected Chairman. It was decided at that meeting that the chief executive officer should be, temporarily, the head of a special committee known as the "Advisory Committee", consisting of Mr. P. H. Rolfs, Director of the Florida Experiment Station of the University of Florida, Gainesville; Mr. L. S. Tenny, Secretary-Manager of the Florida Growers' and Shippers' League; and Mr. W. J. Krome of Homestead, Florida. Rules were adopted by the Board, under the provisions of the Plant Act, primarily for the eradication of citrus canker. At the second meeting of the Board on 10 May 1915, it was decided that the chief executive officer of the Board should be known as the "Plant Commissioner" and that the work of the Board should be divided into 4 departments: Citrus Canker Eradication, Nursery Inspection, Plant Pathology, and Entomology. A fifth department known as the Port and Railway Inspection was added subsequently. Miss Ella Evans was appointed stenographer for the SPB 1 June 1915.

The Plant Act provided that the offices of the SPB shall be located at the University of Florida, Gainesville. The SPB was housed on the second floor of Language Hall (now Anderson Hall) in September 1915. An entomology laboratory and storerooms were located in the attic of Language Hall. Facilities for fumigation and disinfection were established in the basement. At the first meeting of the Plant Board, Dr. E. W. Berger, former Inspector of Nursery Stock, University of Florida, was appointed the Entomologist. Mr. A.C. Mason was appointed assistant entomologist, 3 January 1916. The salaries in 1916 for the entomology staff were: Dr. Berger $2,500, Mr. Mason

[1]Editors note: The Florida Entomological Society dates back to January 5, 1916, when eleven men interested in an entomological society met in Science Hall on the campus of the University of Florida. Of the eleven charter members, 6 were associated with the State Plant Board, now the Division of Plant Industry (DPI). These men were Drs. Wilmon Newell, E. W. Berger, K. E. Bragdon, J. C. Goodman and H. L. Dozier. Since then, 8 members of DPI have served as President, and 8 have served as Editor or Associate Editors of the Florida Entomologist. Seven have been named Honorary Members. The Society is truly indebted to the Entomologists of DPI for their many contributions.

$1,200, and Miss Evans $220, annually. Later, Mr. Mason enlisted in the armed services and the assistant's position was filled by Mr. C. E. Wilson. Mr. Wilson published *Some Florida Scale Insects* for the Entomology Bureau in 1917 and enlisted in the armed services in early 1918. He was followed by Mr. F. F. Bibby who also entered the armed services 10 April 1918. In 1919, Mr. George B. Merrill transferred from the Department of the Port and Railway Inspection to the assistant entomologist's position.

Following Dr. Berger's appointed in 1915, he equipped the laboratory and insectary in the attic, and a general laboratory for identifying and preserving arthropod specimens was located on the second floor of Language Hall. Dr. Berger carried out 3 principal lines of work: 1) the growth and distribution of red aschersonia fungus, *Aschersonia aleyrodis* Webber for the control of whiteflies; 2) rearing the vedalia beetle, *Rodolia cardinalis* (Mulsant), to control cottony cushion scale (ten adult vedalia beetles were sold to growers for 1 dollar); and 3) to develop a control for the camphor thrips, *Liothrips floridensis* (Watson).

The Entomology Bureau, first known as the Entomology Department, was established at the time the SPB was created to regulate, quarantine, and eradicate insect infestations. Incidental work consisted of answering inquiries from farmers and fruit growers regarding insect problems, and preparing special reports on injurious insects and their habits. Records were kept on the distribution of injurious insects in the State as it related to quarantine regulations adopted by the Board, and preservation of insect specimens was made for future reference and information. Less than 1,000 specimens were added to the collection each year for the first 35 years. A fumigation chamber was also constructed to be used for experimental purposes and for fumigating plants which required such treatment before the plants could be sold safely.

The Plant Commissioner, Ed L. Ayers was hired in 1950 to expand the activities of the SPB, including the development of an arthropod collection, later to be known as the Florida State Collection of Arthropod (FSCA).

The SPB offices were moved from Language Hall to the Seagle Building in 1935. In January 1961, the title of State Plant Board was changed to the Division of Plant Industry (DPI) and in 1967 the offices were moved to the newly-constructed Doyle Conner Building, adjacent to the University of Florida Campus. The Entomology Bureau was housed in 7,800 sq. ft. of office and museum space. An addition in 1981 increased the space to 12,960 sq. ft. A biological control security building (4,800 sq.ft.) was dedicated in 1973. This was the first security building for handling exotic arthropods in the southeastern U.S.A. A second biological security building (4,000 sq. ft.) was dedicated in 1989.

The history of any organization is closely tied to their personnel. Thus the remainder of this paper will detail the background and activities of the professional Entomologists of the Bureau. A listing of all personnel who have worked with the Bureau is given in Appendix 1. Photographs of the Chief Entomologists are shown in Fig. 1 and the Entomology Staff in Fig. 2. Support Staff are shown in Fig. 3 and 4.

Dr. E. W. Berger was born in Berea, Ohio, 29 November 1869. He received the BA degree from Baldwin-Wallace College in 1891, the PhB degree in 1894 from the same institution, and the PhD from John Hopkins in 1899. He held the chair of biology at Baldwin-Wallace College during 1899-1901. He came to the University of Florida as the entomologist of the Experiment Station located in Lake City in 1906-1911. He became the State Nursery inspector 1911-1913 and worked under the Board of Control with an office in Rolfs Hall. In May 1915 he became the entomologist to the newly formed SPB and served in that capacity until June 1943. He retired due to failing eyesight and a chronic disease, diabetes. Dr. Berger was admitted to the hospital with an infected foot and died 3 days later on 24 August 1944.

Dr. Berger was best known for his research in the control of citrus insects, especially whiteflies, by the use of a fungus, red aschersonia, *Aschersonia aleyrodis* Webber. He developed a method for growing this fungus on sweet potato and until 1943 supplied it to citrus growers. He received a silver medal for this work at the International Entomological Congress in London, 1912. It was said he put the “fun” in fungus. He also discovered that there were 2 species of whiteflies on citrus, namely *Dialeurodes citri* (Ashmead) and *Dialeurodes citrifolii* (Morgan).

While he was the State nursery inspector, he discovered citrus canker in the U.S.A. in Jefferson County, Florida, 30 September 1912. In July 1913, it was found in Dade County. In July 1914, the growers had abandoned hope of curing infected trees and adopted a campaign of eradication by burning infected trees. The Florida Growers and Shippers' League contributed $17,770, the growers of Dade County contributed $30,000, and Governor Park Trammell contributed $1,000 out of his contingency fund for the eradication program. By the end of 1914, the disease had been found in 7 more counties. The U.S. Congress appropriated $35,000 to investigate the possibility of eradication of citrus canker. This mounting pressure to eradicate the disease lead to the Florida Plant Act, 30 April 1915, which provided the legal organization to deal with the citrus canker and other similar problems. A special fund of $125,000 was appropriated as well as an annual budget of $35,000 to eradicate citrus canker. The disease was soon found in Texas, Louisiana, Mississippi, and Alabama. The U.S. Congress appropriated $300,000 to eradicate citrus canker from the United States on 28 February 1916 and an additional sum of $250,000 on 11 August 1916.

Mr. George B. Merrill, who became Chief Entomologist following the death of Dr. Berger, was born in North Abington, Massachusetts in 1886 and attended Massachusetts Agricultural College and the University of Florida where he received a BSA degree in 1933. His early work was with gypsy and brown-tailed moths in Massachusetts and with sugarcane insects in Puerto Rico. He later became a specialist in the Coccoidea, and authored a book, *A Revision of the Scale Insects of Florida*, published in 1953. Mr. Merrill served as president of the Florida Entomology Society for 3 terms in 1920, 1923, and 1924. After retirement on January 1956, he was elected to honorary membership in the Florida Entomological Society in 1957 and was awarded a citation by the Society in 1968 for his distinguished service. Mr. Merrill died 28 June 1971 in Gainesville, Florida.

Mr. George W. “Wally” Dekle joined the SPB on 1 January 1941 as an assistant grove inspector. Mr. Dekle was born in Ocala, Florida, 4 November 1915 and attended the University of Florida receiving the BSA degree in June 1941. He enlisted in the U.S. Army on 20 March 1942 and served until 1946, after which he returned to the SPB 10 April 1946 as an assistant grove inspector. On 1 July 1947, Mr. Dekle was appointed assistant entomologist specializing in scale insects and immature Lepidoptera. He published the second revision of the armored scales of Florida in 1965 in the Arthropods of Florida and Neighboring Land Areas Series Volume 3. Mr. Dekle served as President of the Florida Entomological Society in 1964 and was honored with the Entomologist of the Year award in 1976 by the Florida Entomological Society. He retired in 1976, and lives with his wife in Gainesville.

Dr. Howard V. Weems, Jr. was born in Rome, Georgia, 11 April 1922. He received a BA degree in 1945 from Emory University and a MS degree in 1948 from the University of Florida. From September 1948 through June 1949 he was an instructor at the University of Mississippi. He received a PhD degree in 1953 from Ohio State University and later that year (1 August 1953) joined the SPB as an entomologist. He later became the head curator, developed the Research Associate program, and was the editor of the Arthropods of Florida and Neighboring Land Areas and Occasional

Papers of the Florida State Collection of Arthropods. Dr. Weems served as an Associate Editor of the Florida Entomological Society from 1973 to 1992. He was responsible for the identification and curating of adult higher Diptera (suborder Brachycera) and miscellaneous smaller arthropod groups. He was also responsible for identifying the Coleoptera, Hymenoptera, millipeds, and centipeds until specialists in these groups were eventually added to the staff. His specialty was the family Syrphidae. Dr. Weems retired 28 February 1991 with over 38 years service, and he continues to serve as an entomologist emeritus. He and his wife live on Redwater Lake near Hawthorne.

Mr. Harold A. Denmark was born in Lamont, Florida, 3 July 1921. He attended the University of Florida and received the BSA degree in 1952 and the MS degree in January 1953. While he was an interim instructor in the Department of Entomology, University of Florida (January to June 1953), Mr. Denmark accepted an entomologist position with the SPB 1 July 1953. He was appointed acting Chief Entomologist January 1 1956 to 10 October 1958, and Chief of Entomology 11 October 1958. In addition to his administrative duties, he was responsible for identifying and curating the Aphididae, Thysanoptera, and the Acari (mites and ticks). He developed and chaired the Arthropod Introduction Committee and initiated the monitoring of the arthropods, and the entomophogous insects, nematodes, and pathogens sold in Florida. His interest in biological control lead to the construction of 2 security biological control buildings. The mite family Phytoseiidae was his special interest group in taxonomy. Mr. Denmark served as the President of the Florida Entomological Society in 1970 and was honored by this Society with the Achievement Award for his research in 1982. Since retiring on 31 August 1992 with over 39 years service with the State, he continues to serve as entomologist eneritus and works on his mite studies. He and his wife continue to live in Gainesville.

Dr. Frank W. Mead was born in Columbus, Ohio 11 June 1922, and attended Ohio State University where he received the BS degree in 1947 and the MS degree in 1949. He joined the SPB 15 October 1953, but took a leave of absence from 1958 to 1960 to attend North Carolina State University where he received the PhD degree in 1968. Dr. Alva Peterson, entomology professor at Ohio State University, had just retired; he filled Dr. Mead's position during his absence. Dr. Mead is responsible for identifying and curating the lower Diptera, suborder Nematocera which includes the mosquitoes and the midges; Homoptera: Psyllidae, plus the suborder Auchenorrhyncha, which includes leafhoppers, planthoppers, spittlebugs, treehoppers, and cicadas, plus the true bugs (Heteroptera). He specializes in the identification of the planthoppers, Cixiidae. In the absence of a State Plant Board photographer, Dr. Mead spent considerable time taking and developing photographs, primarily of entomologists, but also for various departments of the SPB and the Florida Entomological Society. His efforts documented many regulatory activities and his excellent photographs still endure and are in use today for many purposes. He also has photographed entomologists from many parts of the world and he makes these photos available to individuals and journals that recognize these scientists for various reasons. Dr. Mead served as Chairman of the Economic Insect Survey from 1963 until 1978 and has also been the editor for *Triology* for the Bureau of Entomology since soon after its inception. He was honored by the Florida Entomological Society with the Entomologist of the year award in 1981. In the fall of 1993, he received the 40 year Service Certificate.

Dr. Roger A. Morse attended Cornell University where he received the PhD degree in 1955. He came with the SPB 15 January 1955 as an Entomologist, but he terminated his position with the SPB 7 February 1957 to join the staff of the University of Massachusetts Agricultural Experiment Station, Waltham, Massachusetts. In September 1957 he joined the Entomology staff at Cornell University.

Mr. Howard M. VanPelt was born 14 October 1914, and he attended the University of Florida, receiving the BSA degree in Forest Entomology June 1950. He joined the SPB in 2 June 1950 as a grove inspector, but transferred to the Entomology Bureau February 1954 to assist H. A. Denmark with the Economic Insect Survey. He returned to the Bureau of Plant Inspection in January 1957.

Mr. Jesse C. Denmark was born 24 June 1923. He attended the University of Florida and received the BSA degree in Entomology in January 1953. On 9 February 1953, he joined the SPB as a grove inspector and on 1 April 1957 he transferred to the Entomology Bureau to assist with the Economic Insect Survey. Later, he transferred back to the Bureau of Plant Inspection in February 1958 as a Regional Plant Inspector. He retired 16 November 1985 and now lives with his wife in Winter Haven.

Dr. Robert E. Woodruff was born in Kennard, Ohio, on 20 July 1933. He attended Wabash College in Crawfordsville, Indiana in 1951. In 1952, he transferred to Ohio State University and received the BS degree with a major in Entomology in 1956. From 1957 to 1958, he was employed as a medical entomologist with the Kentucky State Health Department in Louisville. In March 1958, he joined the staff of the SPB as the Survey Entomologist until 1963 when Dr. Mead returned. He was responsible for identifying and curating the Coleoptera and Orthoptera. In 1963, he entered graduate school at the University of Florida and received the PhD degree in 1967. Dr. Woodruff retired 31 July 1988, after 30 years of service. His specialty group is the taxonomy of Scarabaeidae. He continues to serve as an FSCA entomologist emeritus and works with the taxonomy, biogeography, and ecology of Scarabaeidae. Dr. Woodruff also serves as a consultant on the Caribbean insects for FAO of the United Nations. He and his wife continue to live in Gainesville.

Dr. Charles C. Porter was born 13 May 1940, in Perth Amboy, New Jersey. He attended Harvard University, receiving the BA degree in 1962 and the PhD degree in 1967. Dr. Porter joined the DPI in January 1972 to identify and curate the Hymenoptera, except for the Formicidae, but he terminated his position 31 March 1972 to take a position with Fordham University. In May 1993, he retired from Fordham and now lives in Gainesville where he continues to support the FSCA as a research associate.

Mr. Stanley V. Fuller was born 4 May 1884, in Eastborne, Sussex, England. He attended Kenelms College in Lewes, Sussex and studied horticulture in England, South Africa, and Australia for 22 years, and later in the United States. In 1958, he began work part time, but died of a heart attack 30 November l966. He was an assistant curator of the Lepidoptera and made hundreds of contributions of specimens over the years, donating most of his private collection of butterflies, numbering over 10,000 pinned, labeled, and identified specimens, to the FSCA upon his death.

Mr. Robert W. Swanson attended the University of Florida from 1952 to 1956 and he joined the SPB on 15 March 1956 as a plant inspector. In January 1968, he transferred to the Entomology Bureau to work on the biology of the caribfly, *Anastrepha suspensa* (Loew), at the Homestead Agricultural Research and Educational Center. He worked with Dr. Richard M. Baranowski until he died on 23 August 1982.

Dr. Eric E. Grissell was born in Washington, D.C., 10 August 1944. He attended the University of California, Davis and received the BS degree in 1964, the MS degree in 1967, and the PhD degree in 1973. Dr. Grissell joined the DPI on 1 June 1973 to identify and curate the Hymenoptera. He resigned 26 January 1978 and took a position with the USNMNH, Washington, D.C.

Mr. Gerd H. Heinrich filled an OPS position from 1975 to 1977 to complete his studies on the Ichneumoninae of Florida and the southeastern United States. Mr. Heinrich was born in Berlin, Germany on 7 November 1896. He graduated from Askanische Gymnasium in Berlin in 1917. Like his father before him, he had planned toward a career in medicine; however, his education was interrupted by the declaration of war between Germany and Russia. He entered the German Air Force and became a pilot. After the war (World War I), he married and lived with his family in West Prussia (since 1918, Poland). Poland was invaded by Germany in 1939 and World War II began. A series of bizarre incidences followed after which he and his family later escaped to West Germany under extremely dangerous circumstances. In 1951, they moved to the United States, became American Citizens, and settled in Maine. His *Ichneumoninae of Florida and Neighboring States* was published as volume 9 of *The Arthropods of Florida and Neighboring States* in December 1977.

Dr. Avas B. Hamon was born 8 March 1940 in Ripley, West Virginia and attended Morris Harvey College (now the University of Charleston) for the BS degree, Marshall University for the MS degree, and Virginia Polytechic Institution and State University for the PhD degree. He joined the DPI 11 October 1976 to identify and curate the Homoptera: Coccoidea and Aleyrodidae.

Dr. Lionel A. Stange was born 27 June 1935 in Los Angeles, California. He attended the University of California, Berkley for the BS degree and University of California, Davis for the MS and PhD degrees. Dr. Stange joined the DPI 3 February 1978 to identify and curate the Hymenoptera, gall forming insects, Neuroptera, snails and slugs. From 1966 to 1978 he was employed by the University of Tucuman, Tucuman, Argentina. His specialty group is the family, Myrmeleontidae: Neuroptera.

Dr. John B. Heppner was born 18 November 1947 in West Germany, but attended the University of California, Berkley for the BS degree and the University of Florida for the PhD degree in 1978. He was awarded a Smithsonian predoctoral fellowship from 1976 to 1978. He joined the DPI 11 February 1983 to identify the Lepidoptera and immature insects, particularly fruit fly larvae.

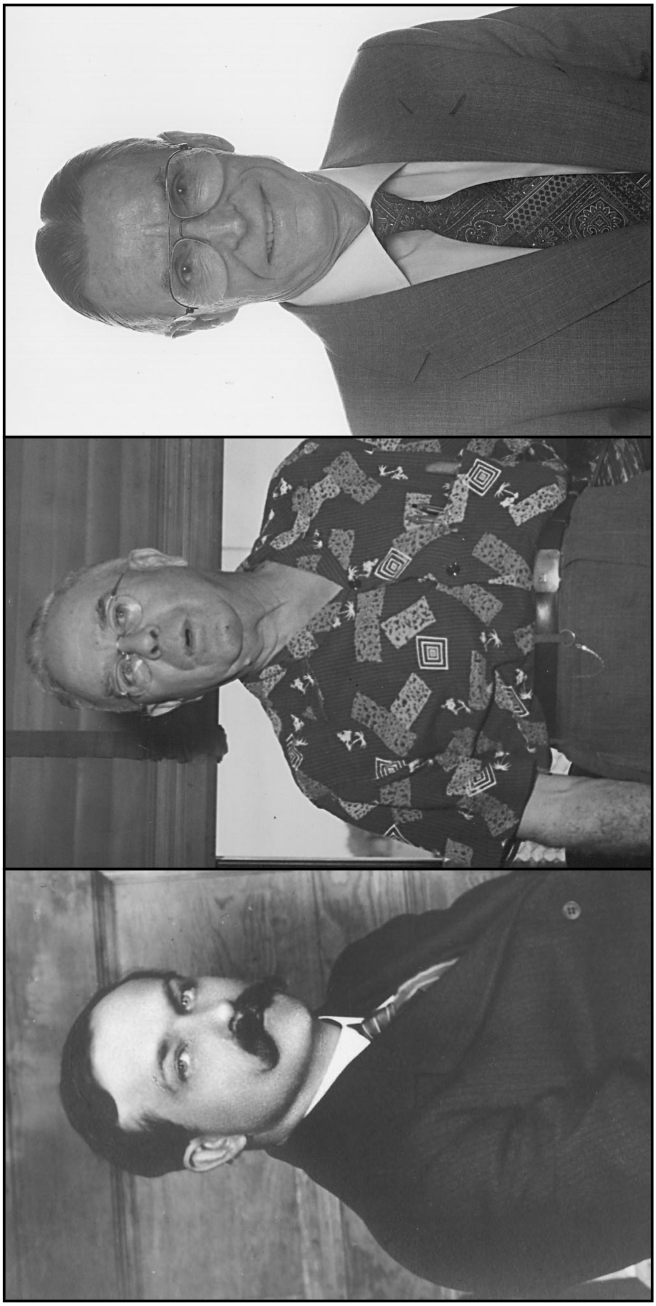
Dr. G. B. Edwards was born 24 November 1948, in Aberdeen, Maryland. He attended the University of Maryland and received the BS degree in 1971 and the MS degree in 1975. Dr. Edwards received the PhD degree in 1980 from the University of Florida. He joined the DPI as a Laboratory Technician II on 31 March 1978 and later was reclassified to a Laboratory Technician IV. On 27 July 1984, his position was reclassified to a Biological Scientist III and on 23 August 1985 to a Biological Scientist IV. Dr. Edwards is responsible for curating and identifying all non-insect arthropods except the Acari.

Dr. Michael C. Thomas was born in Miami, Florida, 5 May 1948. He attended the Miami-Dade Junior College and received the AA degree in April 1968 and the BA degree from the University of South Florida in December 1970. He worked as a reporter/news editor from January 1971 to July 1972 for the Punta Gorda Daily Herald News, Punta Gorda, Florida, and 1972 to 1977 as a reporter/bureau chief, Orlando Sentinel Star in Melbourne, Vero Beach, and Ocala. From November 1977 to August 1983 he was Research Editor, Division of Information and Publication Services of the University of Florida, Gainesville. He was a Graduate Assistant in August 1983, in the Department of Entomology and Nematology, University of Florida and received the MS degree, University of Florida in August 1981 and the PhD degree in 1985. He accepted a position with the University of Florida and worked with Dr. Gary Buckingham, Gainesville, on aquatic weed control from August 1985 to 1 March 1986. He accepted a position with the West Virginia Department of Agriculture from 3 March 1986 to 1 July 1988. On 29 July 1988 he accepted a position with the DPI as an entomologist to curate and identify the Coleoptera and Orthoptera.

Dr. Gary J. Steck was born 31 March 1951, in Owosso, Michigan. He received a BS with a major in zoology in 1973 from the University of Michigan. A year of under-graduate study was spent in residence at Albert-Ludwig Universitat in Freiberg i/Br, West Germany. The dissertation, entitled *North American Terelliinae (Diptera: Tephritidae): Biochemical Systematics and Evolution of Larval Feeding Niches and Adult Life Histories*, was completed in 1981, and he was awarded the PhD degree from the University of Texas. Postgraduate work continued at Texas A&M University, Department of Entomology from 1981 to 1987. From 1988 to 1991 he worked as a research entomologist with the USDA-ARS-Systematic Entomology Laboratory, Beltsville, Maryland. In 1991, he joined the SPB Entomology Bureau as a taxonomic entomologist in Diptera, primarily Tephritidae and Otitidae. Other duties include coordinating the Research Associate program of the FSCA and as an Associate Editor of the *Florida Entomologist*.

SUMMARY

Dr. E. W. Berger served as Chief Entomologist from May 1915 to June 1943. Mr. G. B. Merrill served as Chief Entomologist from July 1943 to December 1955. Mr. H. A. Denmark served as Acting Chief Entomologist from January 1956 to June 1958 and Chief from July 1958 to 31 August 1992. On 1 September 1992, the Bureaus of Entomology, Nematology, and Plant Pathology were combined into 1 Bureau under 1 chief. The former chiefs' positions became Biological Administrators III. Dr. Wayne N. Dixon was appointed the Chief of Entomology, Nematology, and Plant Pathology Bureau on 31 December 1992. Dr. Michael C. Thomas was appointed the Biological Administrator III of the Entomology Section 29 October 1993. Dr. T. S. Schubert's title was changed from Chief of Plant Pathology to Biological Administrator III of Plant Pathology Section 1 September 1992.



Dr. E. W. Berger
1915-1943

Dr. George W. Merrill
1943-1956

Mr. Harold A. Denmark
1956-1992

Fig. 1. Chief Entomologists for the Bureau from 1915 to 1992.

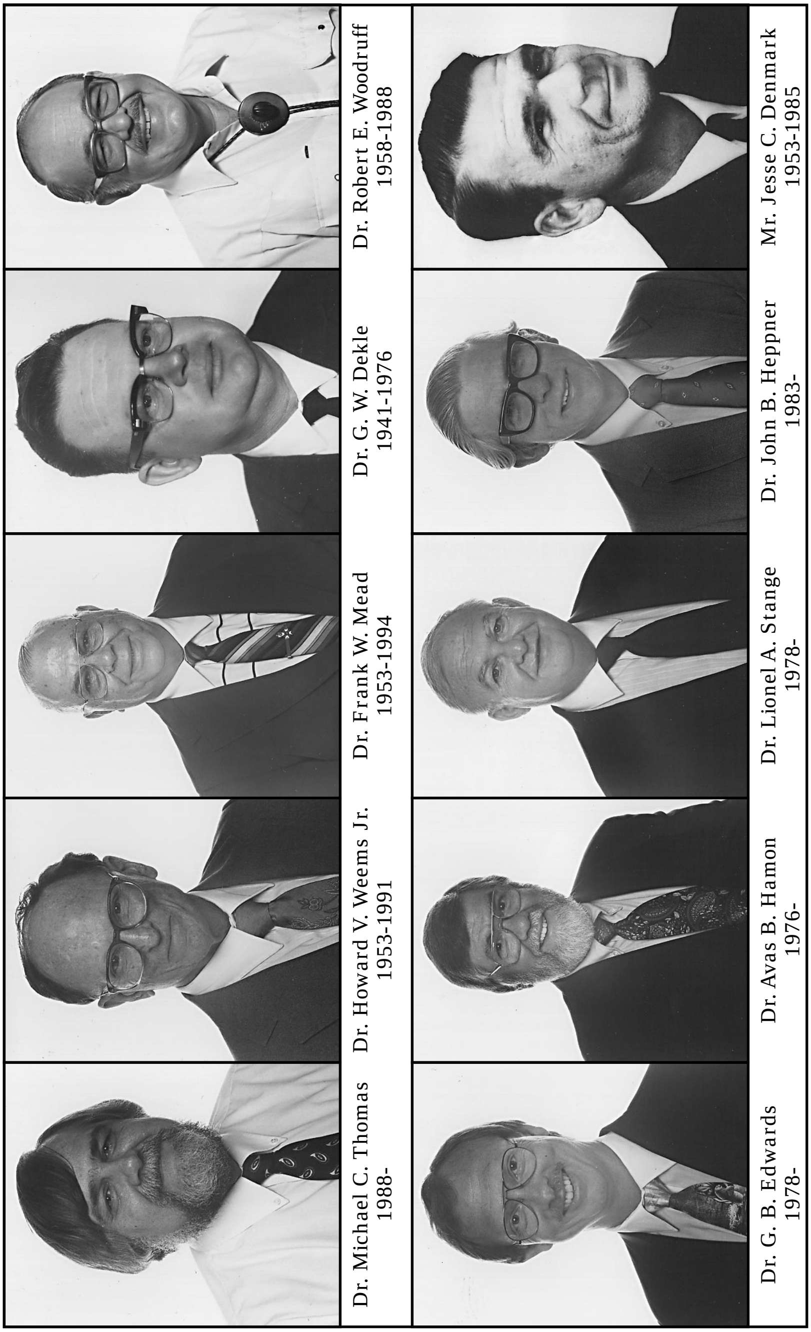


Fig. 2. Entomological Staff for the Bureau from 1941 to present.

Fig. 3. Support Staff. July 3, 1966: Left to right, Lodonia (O'Berry) Fields, Joyce Keel, Helen Harben, Dr. Frank W. Mead, Ernestine (Mercer) Ostanik, Margret Shaftner, George W. (Wally) Dekle, Annett Dugger, Dorthy Mae Dugger, Mary Monroe, and Harold A. Denmark.

Fig. 4. Support Staff. September 6, 1979: Left to right, Mary Monroe, Elaine Sims, Patrica Sessler, Dr. Avas B. Hamon, Helen Harben, Ann Britton, Brenda Beck, Darlene Cannon, Ernestine (Mercer) Ostanik, and Janet Temple.

APPENDIX I

SUPPORT PERSONNEL FOR THE ENTOMOLOGISTS FROM 1953 TO 1993

George B. Merrill, Entomologist
- Secretary
  - Louise Reddick

Harold Denmark, Entomologist
- Secretaries
  - Mary Monroe
  - Byrdie Lanier
  - Brenda Moore
- Clerk Typists
  - Mary (Dolly) McClenny
  - Nancy Thomas
- Technicians
  - Dorthy Holman
  - Elizabeth Womer
  - Ladonia (O'Berry) Fields
  - George Carter
  - John Waldrop
  - Amy Baker
  - Scott Yocom
  - Steve Gillis
  - Charles (Chuck) Hernandez

Howard V. Weems, Jr., Entomologist and Head Curator
- Secretaries
  - Grace Thomas
  - Jane Raybourn
  - Annette Dugger
  - Carmen Thibault
  - Betty Harvey
  - Ethel Quinn
  - Gretchen Davis
  - Donna Alverson
  - Katrina Vaughn
  - Ann Britton
  - Angela Cauldwell
  - Cathy Watson
  - Lynda Johns
  - Evelyn Anglehart

George W. Dekle
- Secretaries
  - Linda Hammock
  - Janet Cunningham
  - Roberta Casto
  - Margaret (Betty) Graham

Robert E. Woodruff, Entomologist
- Secretaries
  - Marilynn Morison
  - Joyce Keel
  - Mary Papuzynski
  - Patricia Shoemaker
  - Irene Ayres
  - Gayle Albritton
  - Pam Fey
  - Sally Leistikow
  - Elizabeth Manning
  - Deidra Proveaux
  - Frances Williams
- Technicians
  - Brenda Beck
  - Patrice Gataitis

Frank W. Mead, Entomologist
- Secretaries
  - Francis Paterno
  - Gayle Farnell
  - Cyndy Mallory
  - Terri Byrd
  - Sharlynn Mann
  - Terry Green
  - Charlotte Burkette
- Technicians
  - Bonnie Brinkerhoff
  - Bob Weston

Avas B. Hamon, Entomologist
- Secretaries
  - Pam Zwerski
  - Elaine Sims
  - Joan Ortagus
  - Darlene Cannon
  - Pam Zwerski
  - Pam Meister
  - Pam Exxon
  - Janet Miller
- Technician
  - Ernestine Ostanik

G. B. Edwards, Entomologist
- Secretary
  - Charlotte Burkette

Technician
Paul Skelley

Gary Steck, Entomologist
Secretary
Evelyn Anglehart
Technician
Kurt Ahlmark

Michael C. Thomas, Entomologist
Secretary
Michelle Faniola
Technician
Paul Skelley

John B. Heppner, Entomologist
Secretary
Charlotte Burkette
Technician
Bob Weston

Lionel A. Stange, Entomologist
Secretary
Michelle Faniola
Brenda Lovelace
Technician
James Wiley

Eric Grissell, Entomologist
Technicians
Jennifer Jennings
Phyllis Habeck

Calvin Welbourn, Entomologist
Secretary
Brenda Lovelace
Technician
Charles Hernandez

EDITED MINUTES OF THE 77TH ANNUAL MEETING, FLORIDA ENTOMOLOGICAL SOCIETY

The fourth and final 1993-94 Executive Committee meeting was held on August 8, 1994, at the Indian River Plantation Resort in Stuart, Florida. President Jorge Peña called the meeting to order at 4:30 p.m. Minutes of the April 12, 1994, business meeting submitted by the FES Secretary were accepted as submitted. Business Manager Ann Knapp distributed reports on the Society's finances; David Hall moved to accept the reports; motion seconded by Cliff Lofgren; the reports were accepted by voice vote. The report of the Fiscal Committee was accepted as submitted. Hall reported that Harold Denmark had sent FES a letter thanking the Society for his Honorary Membership. Preliminary final reports of other committees were presented by respective Chairmen. The meeting adjourned at 5:40 p.m.

The 1993-94 Annual Business Meeting of the Society was called to order by President Peña at 5:00 p.m., Tuesday, August 9, 1994. A total of 43 Society members were present. Minutes of the 1993 meeting at Captiva, Florida, were accepted as published in *Florida Entomologist* 76(4): 659-667. Final reports from the various standing and ad hoc committees of the Society are presented herein. President Peña passed the gavel to the new president, Ellen Thoms. No further business was discussed. The meeting was adjourned at 5:30 p.m.

REPORT OF THE BUSINESS MANAGER
JULY 1, 1993 TO JUNE 30, 1994

RECEIPTS:	
Membership	$14,080.00
Subscription	6,045.00
Annual Meeting	12,486.28
Dividends	1,969.85
Student Activities	400.00
Miscellaneous	106.04
Refunds	(30.00)
Contributions	100.00
TOTAL	$35,157.17
EXPENSES	
Office Expenses	$190.89
Contract Labor	11,750.00
Postage	357.78
Contributions	200.00
Travel	1,250.37
Grants & Scholarships	2,500.00
Printing Journal	359.34
Editing	721.20
Newsletter	169.91
Miscellaneous	500.00
Dues & Subscriptions	90.00
Annual Meeting	11,400.38
Student Activities	2,190.00
Special Projects	900.00
Bank Charges	175.25

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TOTAL	$32,773.12
NET GAIN	$2,384.05

ASSETS:		MEMBERSHIP:	
Petty Cash	$100.00	Full	438
Cash in Bank	72,755.91	Student	74
		Sustaining	48
		Honorary	9
		Emeritus	11

ANN C. KNAPP, BUSINESS MANAGER

REPORT OF THE FISCAL COMMITTEE

Status of Society Financial Records:

FES financial records for the period July 1, 1993, to June 1, 1994, were examined on August 3, 1994. The committee found all records in order.

F. PETITT, CHAIRMAN; S. WEBB; D. SEAL; D. WOJCIK

REPORT OF THE PROGRAM COMMITTEE

The Program for the Seventy-Seventh Annual Meeting of the Society consisted of 4 symposia comprised of 23 speakers, 31 submitted papers, 12 student papers, 14 display posters, and 1 workshop. The keynote speaker was Lincoln P. Brower. There were 218 registrants at the meeting (142 full, 16 student, 49 spouses, 11 gratis).

J. A. COFFELT, CHAIRMAN; D. OI; P. GREANY; E. MITCHELL; J. MINK; E. THOMS; M. HOY; J. H. FRANK; M. J. HAYES; AND M. VATHAKOS

REPORT OF THE LONG-RANGE PLANNING COMMITTEE

(1) The committee recommends that the Society continue to develop programs to inform the public, particularly young people, about the profession of entomology. In addition, we suggest that a permanent public outreach committee be appointed by the Society's President to implement these programs.

(2) The committee recommends that an advisory/liaison committee consisting of knowledgeable members from various groups of the Society, including the Florida Department of Agriculture's Division of Plant Industries, be considered by the membership to help address requests from organizations outside the Society related to priorities and risks of exotic pest introductions.

(3) The committee recommends that the establishment be considered of an international outreach/liaison committee to correspond and assist interested people in obtaining visa applications, specimen collection permits, and copies of journals.

(4) The committee recommends that the Society play an active role in identifying and promoting critical research needs of the science of entomology. It is suggested that one major scholarship be made available each year to support a graduate student working in a critical area of entomology. The critical topic should be changed as time evolves to allow the Society to make a timely statement about scientific needs and enhance the recognition of Society efforts to address critical topics of the day.

F. C. TINGLE, CHAIRMAN; S. BRODA-HYDORN; J. CHAMBERLIN; J. MINK

REPORT OF THE HONORS AND AWARDS COMMITTEE

This year the Florida Entomological Society is proud to recognize and honor 11 individuals for their contributions to the discipline of entomology and to the Society.

Entomologist of the Year: Ernest S. Delfosse

Dr. Ernest S. Delfosse is the inaugural Director of the National Biological Control Institute, establishing it as a viable force in entomology both in the state of Florida, and globally. Under his leadership the NBCI has issued grants during the past 4 years for a number of projects including black parlatoria scale, *Thrips palmi*, and the Russian wheat aphid. He authored and gained endorsement for the official Biological Control Philosophy for USDAs-Animal Plant Health Inspection Service. Application of this philosophy is evident in the use of parasites to help maintain the fly-free zone for grapefruit export from Florida. Dr. Delfosse has led a major effort to renew biological control regulations for the importation and release of natural enemies in the U.S. Moreover, he has fostered significant increases in public education, environmental monitoring, interdisciplinary research and implementation, and international cooperation in biological control. Dr. Delfosse is President of the Global Council, International Organization for Biological Control. He serves on numerous interdepartmental government committees in the U.S., he has published more than 80 scientific papers and edited six books. Dr. Delfosse contributed to the Commonwealth Scientific and Industrial Organization, Division of Entomology, winning the inaugural "Eureka Prize for Environmental Research". He supervises graduate students in Australia, Africa, and the U.S., and helped to develop and implement the Australian Biological Control Act. He has attained this international scientific prominence while maintaining his affiliation and active membership in our Society. Therefore, the Florida Entomological Society proudly presents the Entomologist of the Year Award for 1994 to Dr. Ernest S. Delfosse.

Annual Achievement Award for Research: Robin M. Giblin-Davis

Our recipient this year is Dr. Robin M. Giblin-Davis. Dr. Davis has produced over 50 refereed publications and book chapters on the chemical ecology of weevils and entomopathogenic nematodes. As a product of this research effort, Dr. Davis has developed effective monitoring and trapping systems for *Rhynchoporus* spp. Subsequently, this work has resulted in the use of effective control systems in Central America and Florida against the palm weevils. The Florida Entomological Society presents the 1994 Annual Achievement Award for Research to Dr. Robin M. Giblin-Davis.

Special Award for Research Teams: Russ Mizell, Peter Andersen and Brent Brodbeck

This award goes to Russ Mizell, Entomologist, Peter Andersen, Horticulturist, and Brent Brodbeck, Senior Biologist. These entomologists have worked cooperatively, and with other members of the faculty at NFREC-Monticello, as an outstanding example of an interdisciplinary approach that is often required to solve today's complex agricultural problems. This interdisciplinary team and their colleagues have quantified physiological effects of insect feeding and biochemical and biophysical determinants of leafhopper feeding and its associated pathogen and plant interactions. Their ten publications on these interactions serve as a major source of information on xylophagous insects. A large NRI-biostress grant from the USDA was awarded in 1992 to support the research. The Florida Entomological Society presents the 1994 Special Award for a research team to Russ Mizell, Peter Andersen, and Brent Brodbeck.

Annual Achievement Award for Extension and Industry: Charlie D. Morris

The Award for Extension and Industry goes to Charlie D. Morris. Since assuming his current role as extension medical entomologist in the late 1980's, Charlie has effectively stimulated research and coordinated the release of information documents, films, tapes and displays. Dr. Morris conceived, initiated and has been the driving force and Senior Editor since the inception in 1990 of Wing Beats, a quarterly publication jointly sponsored by the Florida Mosquito Control Association and the American Mosquito Control Association. During the same period, he has produced a formal monthly newsletter called "Buzz Words" for FMCA. In 1993, he coordinated a 2-hour video training conference on mosquito control through an interstate satellite video and telephone linkage to 16 sites in the southeast, attracting over 200 paid registrants. In addition, he plays a leading role in the planning and execution of the FMCA short course, which annually attracts over 300 paid registrants for a week of formal training in various aspects of mosquito biology and control. The Florida Entomological Society presents Charlie D. Morris with the 1994 Annual Achievement Award for Extension and Industry.

Teacher of the Year, K-12 Award: Stephen C. Crandall

This inaugural annual award recognizes the entomological contributions provided by K-12 teachers. This likely is the first entomological encounter for our youth, and with the exposure to this scientific discipline, our future entomology students and professionals may become inspired by these teachers. Thus, the Florida Entomological Society will honor this group of educators and the profoundly important service that they perform. This year's award is to an 8th grade science teacher and Chair of the Science Department at the Inverness Middle School, Mr. Stephen C. Crandall. Mr. Crandall embarked on a dream a few years ago, to develop an environmental center as a laboratory for students to understand ecology and environmental issues using insects and their ecological interactions. He designed and built this Outdoor Nature Center in 1992. Since then, Mr. Crandall has developed computer-based, multimedia educational modules, including the use of laser videodiscs, to teach entomology and ecology. He also has written a computer-aided key to the orders of insects for his students' use. Mr. Crandall has taken his techniques and technologies beyond his middle-school students, and has conducted several special workshops to over 50 other science teachers throughout the state. Thus, it is with great pride that the Florida Entomological Society makes this inaugural award for the K-12 Teacher of the Year to Mr. Steven C. Crandall.

Recognition of the President: Jorge E. Peña

The Honor and Awards Committee wishes to recognize our outgoing president, Jorge E. Peña, for outstanding dedicated service as President of the Florida Entomological Society for the 1993- 1994 year, culminating in this 77th Annual Meeting.

Certificate of Appreciation: James A. Coffelt

The Society awards a Certificate of Appreciation for his exemplary service in planning and organizing the program for the 77th Annual Meeting.

Certificate of Appreciation: David H. Oi

A Certificate of Appreciation is awarded for his exemplary service in assisting in organizing the program for the 77th Annual Meeting.

Certificate of Appreciation: George F. O'Meara

The Society awards a Certificate of Appreciation for his exemplary service as Chairman of the Local Arrangements Committee for the 77th Annual Meeting.

Presidential Recognition Award: David G. Hall

For his exemplary service above and beyond the call of duty as Secretary of the Society for three terms, encompassing 1991-92, 1992-93 and 1993-94.

Presidential Recognition Award: J. Howard Frank

For exemplary service to the Society in planning and organizing the Caribbean Directory of Entomologists, and in co-organizing the Behavioral Ecology Symposia for the period of 1988 through 1994.

RICHARD J. BRENNER, CHAIRMAN; R. SPRENKEL; P. KOEHLER; D. WOJCIK

REPORT OF THE STUDENT ACTIVITIES COMMITTEE

There were 12 applications for the 10 $100 mini-grants, which were awarded as follows: Marci Aparicio (UF), Maria Cattell (Univ. South Florida), Alex Cordoba-Aguilar (Instituto de Ecologia, Xalapa, Veracruz, Mexico), Tom Dykstra (UF), Avi Eitam (UF), Guangye Hu (UF), Eric Hudson (Univ. South Florida), Christine Masson (UF), Dini Miller (UF), and Michael Windelspecht (Univ. South Florida).

There were 12 applications for the 3 $500 scholarships, which were awarded to Paula Cushing (UF), Odair Fernandes (Univ. Nebraska), and Steven Valles (UF).

Eleven papers, all by UF students, were submitted for entry in the student paper contest. First place ($125) was awarded to Dini Miller, second place ($75) to Steven Valles, and third place ($50) to Marci Aparicio.

Travel grants of $230 each to attend the 1993 Entomological Society of America Annual Meeting in Indianapolis were provided for UF Linnaean team members Greg McDermott, Margaret McMichael, Faith Oi, Marco Toapanta, and Scott Yocum. Travel grants of $250 each were provided for Guangye Hu, James Okine, and Tom Macom to attend the ESA meeting in Indianapolis. Dini Miller received a travel grant of $200 to attend the Invertebrates in Captivity Conference in Tuczon, AZ in July. James Okine received a $100 travel grant to attend the 1994 FES Annual Meeting.

PATRICK PARKMAN, CHAIRMAN; J. EGER; J. KLOTZ; P. NICHOLS; M. HUBBARD

REPORT OF THE RESOLUTIONS COMMITTEE

Resolution No. 1:

WHEREAS the 75th Annual Meeting of the Florida Entomological Society at the Indian River Plantation Resort and Marina, Stuart, Florida, has enjoyed outstanding facilities and hospitality which immensely contributed to the success of the meeting, AND WHEREAS Terri Monaghan, Director of Public Relations, Indian River Plantation Resort and Marina, generously gave her time and effort to welcome the Society to the city of Stuart, which effectively opened the 77th Annual Meeting of the Society,

THEREFORE, BE IT RESOLVED that the Secretary of the Society be instructed to forward a copy of the resolution to Jeffrey Johnsen, the Resort Manager.

JIM D. HENSEN, CHAIRPERSON; D. KLINE

REPORT OF THE MEMBERSHIP COMMITTEE

LARRY GAST, CHAIRMAN;

REPORT OF THE PUBLIC RELATIONS COMMITTEE

A booth was set up at the Annual Meeting of the Entomological Society of America in Indianapolis, Indiana. Information about FES membership, journal and the 1994 and 1995 FES Annual Meetings were distributed. Graduate students from the University of Florida helped staff the booth.

Information on the 1994 Annual Meeting of the FES were sent to the Entomol. Soc. America newsletter and the Florida State Horticultural Society newsletter for publicity.

NANCY EPSKY, CHAIRMAN;

REPORT OF THE PUBLICATIONS COMMITTEE

Florida Entomologist published 674 pages in volume 76 (1993), 54 more than in Vol. 75 (1992): included in Vol. 76 were 3 symposia with 26 papers, 35 research reports, 15 scientific notes, 11 book reviews, one forum paper, an overview of FES history, one new journal review, 2 *in memoriams*, 2 presidential addresses, and the edited minutes of the 75th and 76th annual meetings. The first two issues of Vol. 77 totaled 300 pages. The September issue is at the printers at this time. Since January 1, 1993, we have received 49 research papers and scientific notes, 9 book reviews, and 4 *in memoriams*.

Since the 1993 annual meeting, 3 associate editors have resigned (W. W. Wirth, John Brower, and Louis B. Bjostad). They have been replaced by Richard Baranowski, Robert K. Vander Meer, and Mary Jo Hayes.

Following our last meeting, we instituted the use of Key Words for research reports and symposia papers and Summaries for scientific notes. In addition, we require all authors to provide accurate billing addresses prior to publication of their papers.

Since our journal states that it is an international journal, I thought it would be interesting to determine the source by states and countries of papers published during my tenure as editor (issues for March, 1993 - September, 1994). To do this, I determined the location of the senior author of all research reports and scientific notes. A total of 90 papers were included in the review. They represented 11 countries (including the U.S.) and 17 states. Twenty-two, or almost 25%, were papers from sources outside the U.S. (Mexico - 7, Brazil - 5, Jamaica - 2, Venezuela - 2, and one each from Guatemala, Trinidad-Tobago, Canada, Colombia, France). Also, slightly less than half came from Florida (48%). States from which more than one paper were received were Texas, Mississippi, California, Georgia, and Hawaii. This information indicates that we are definitely an international journal.

CLIFF LOFGREN, EDITOR

REPORT OF THE NOMINATING COMMITTEE

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

President:	Ellen Thoms
President-Elect:	James Coffelt
Secretary:	Brett Highland
	Frederick Petitt
Vice-President:	Everett Mitchell
	Russell Mizell
Executive Committee Member at Large:	Heather McAuslane
	Philip Stansly

There were a total of 71 ballots returned from FES members. Ellen Thoms was elected President, James Coffelt was elected President-Elect, Frederick Petitt was elected Secretary, Russell Mizell was elected Vice-President and Heather McAuslane was elected Executive Committee Member at Large. The Nominating Committee expresses appreciation to all candidates for their willingness to serve.

President-Elect James Coffelt regrettably turned in a letter of resignation. Jim and his wife, Merle, are making plans to relocate in California. David Williams moved to promote Russell Mizell from the office of Vice-President to President-Elect, and to award the office of Vice-President to Everett Mitchell, second by Thoms. Following a review of Chapter III, Section 2 of the FES By-Laws, the Executive Committee agreed the proposed solution was permissible. The motion passed unanimously. Therefore, the elected FES officers for 1994-95 are: Ellen Thoms, President; Russell Mizell, President-Elect; Everett Mitchell, Vice-President; Frederick Petitt, Secretary; and Heather McAuslane, Member at Large. Lee Bloomcamp will complete her two-year term as Member at Large during 1994-95.
DAVID WILLIAMS, CHAIRMAN; DALE HABECK; J. EGER.

REPORT OF THE SUSTAINING MEMBERSHIP COMMITTEE

The Sustaining Membership Committee enjoyed a very successful 1993-94 term. Sustaining memberships increased by 11 new members - from 40 members in 1992-93 to 51 members in 1993-94. Also, several delinquent sustaining members were contacted and have since paid their dues.

We sent letters to over 70 FES members soliciting financial support for student travel and industry sponsored events for the annual meeting. A total of $1,825.00 was contributed by 16 members, $775.00 for student travel and $1,050.00 for industry sponsored events at the meeting.
KENNETH MUZYK, CHAIRMAN; BRET HIGHLAND; M. LEWIS WRIGHT, JR.

REPORT OF THE 1995 CARIBBEAN CONFERENCE COMMITTEE

The Cariari Hotel in San José, Costa Rica, will be the headquarters for the Third Caribbean Conference of Entomology, August 6-10, 1995. The contract is ready to be signed and has been reviewed by Ann Knapp and J. Peña. Details on making airline and excursion arrangements will be made available soon. Ann Knapp, Joe Knapp and Joe Eger will be handling these details.

The following symposia have been proposed for the 1995 meeting: Insect Vectors of Plant Pathogens (J. Tsai); Citrus Pests in the Caribbean (J. Knapp); Arthropod Predator Conservation (W. Whitcomb & M. Shepard); Training and IPM in the Caribbean (C. Barfield); Biological Control in the Caribbean: Institutions and Services (N. Leppla); and Neotropics as a Resource for Pest Control (R. Jansson).

Brochures for the Third Caribbean Conference were sent by Ellen Thoms to entomologists in the region. Dr. J. Jimenez of INBio offered to help with insect collecting permits. Around 25 people have sent their CV to be forwarded to INBio. J. Peña has asked H. Weems to continue the task of obtaining U.S. permits for bringing in specimens from Costa Rica.

According to Julio Arias, the Entomological Society of Costa Rica would like to have a joint meeting. I have previously written to the Costa Rican Society; I have made phone calls and sent faxes; I have not had an answer yet.

J. PEÑA, CHAIRMAN; E. THOMS; J. EGER; A. WHITE; A. KNAPP; J. KNAPP; J. ARIAS; M. NANCE; W. WEEMS; E. MOHEREK

REPORT OF THE CARIBBEAN DIRECTORY COMMITTEE

The first paper edition of the Caribbean Directory has been produced in 750 copies. The bill from IFAS Educational Media and Services was sent to Ann Knapp. We believe that it is $794 plus a little extra for envelopes, so that cost per copy is only a little over $1. Each FES member during 1994 is to get a free copy. The remaining copies will be available for sale at $5 each, including postage and any applicable sales tax. The Society should not lose on these sales, even to destinations abroad (printed matter, surface mail if this cost is less than airmail).

Eight boxes of 45 copies each were brought to the meeting for distribution by Ann Knapp. The remaining copies are in Howard Frank's laboratory awaiting instructions from A. Knapp for storage.

We will continue to input information to the computer files as it is received. We will attempt, in collaboration with the Computerization Committee, to put the directory onto the Internet this autumn.

We thank Jorge Peña for translating part of the text into Spanish, and we request that he write a personal letter to the president of each of the six entomological societies in the region, enclosing a complimentary copy of the directory.

The end pages of the directory contain an application form for membership in FES, an order form for copies of the directory, information from Ellen Thoms about the 1995 meeting, and information forms for adding and correcting information in the electronic version of the directory.

HOWARD FRANK, CHAIRMAN; GUY HALLMAN; BOB WOODRUFF; CARL BARFIELD

REPORT OF THE COMPUTER RESOURCES FOR ENTOMOLOGICAL INFORMATION

Although no issues of Florida Entomologist are currently on the Internet, prospects are good that one or more will be on by 1 October and that all four 1994 issues will be on by 15 December.

Background

Last August the Florida Entomological Society endorsed a proposal by its Committee on Computer Resources for Entomological Information to publish the Florida Entomologist (FE) on the Internet while continuing with traditional, ink-on-paper publication. Helping make this a reasonable proposal was the cooperation of the Florida Center for Library Automation (FCLA), which had agreed to use *FE* as part of its efforts to make primary literature electronically accessible.

Efficient methods of publishing electronically in parallel with print publication require that the pages be composed electronically. The March 1994 issue of *FE* was produced by cut-and-paste, but with the June 1994 issue Painter Printing began using an electronic page making system that produces Postscript files of all material. Thus, the 1994 volume of *FE* requires two technologies: one that can handle pages having no ready-made electronic equivalents and one that can use electronic files that Painter Printing's new system can produce. The former technology will make it possible to put all earlier volumes of Florida Entomologist on the Internet. The latter can be used for future volumes.

Articles not electronically page set [March 1994 issue (vol. 77, no. 1) and back]

Mark Hinnebusch of FCLA has been working on a system that will largely automate the scanning of journal articles to produce Tagged Image Format (TIF) files. These files are bit-mapped and will enable the user to print articles in the same form as they appeared in FE, i.e., the files will produce the equivalent of photocopies of journal articles. Because they are bit-mapped, the contents of these files cannot be searched or edited unless translated into another form via optical character reading software.

Mark reports that he has solved most of the problems encountered in developing this system and expects to be ready to test it with articles from the March issue of *FE* in the near future.

Articles electronically page set [June 1994 issue (vol. 77, no. 2) and forward].

Painter Printing can easily produce Postscript files of *FE* articles that it has electronically page set. However, when Postscript files were used in last year's pilot test of electronically publishing FES, they proved difficult for most potential users of the online *FE* to view or print. It therefore seemed desirable to look for a more accessible electronic format - such as produced by programs designed to make formatted documents portable. Some of these programs do not suit our purposes because they require proprietary software at both ends, but others enable the recipient of a file to view and reproduce the formatted document with freeware.

Sanford Porter secured demonstration copies of two candidate programs: *Common Ground* by No Hands Software and *Replica* by Farallon Computing. The former did not reproduce figures or photos at acceptable resolution. The latter qualified for further testing.

Jeff Johnston of Painter Printing tested *Replica* by printing, to *Replica* files, articles from the June issue of FE. Initial tests went poorly but he solved many of the problems by consulting with personnel at Farallon. However, some of the problems proved intractable and the present version of *Replica* was deemed unacceptable because of its uneven kerning and its failure to translate certain characters correctly - viz., it rendered *fl* as ∫ and *fi* as π. Farallon acknowledged the deficiencies and informed Jeff that it was developing a version that should obviate the disqualifying problems; unfortunately, the earliest the new version might be available is this fall.

In the meanwhile Word Perfect has entered the make-formatted-documents-portable field with a product named *Envoy*. On 26 July, Jeff ordered *Envoy* and was given a 90-day, money-back guarantee of satisfaction. Should Envoy not produce an acceptable solution by the end of August, we plan to use Postscript files until a better format is available. When we find such a format, we will substitute the more desirable files for the Postscript ones or give the user the option of downloading either format for those articles already mounted. Internet access

Entomologists accessing information on the Internet generally use gopher or www clients or both. In a May 1994 poll of members of the ENTOMO-L bulletin board, 55% of the 40 who responded had access to gopher and www clients, and an additional 35% had access to a gopher but not a www client. *FE* articles should be put on gopher to maximize the number of entomologists that can access them. FCLA has offered us space on their gopher server. Entomologists who prefer to use a www client will not be inconvenienced, because www clients can easily access gopher menus and files.

When we did our 1993 pilot test of publishing *FE* articles on the Internet, we had no way to make binary files easy to download for those unversed in FTP. Now most gopher server/clients can deliver/receive binary files. Therefore, whether our files are ASCII, binary, or both, downloading them from the Internet should be easy.

Gopher menu structure

Three sorts of users of "FE Online" can be postulated:

- ♦ Users who know the citation of a FE article and want to view or print the article (or part of it).
- ♦ Users who wish to browse one or more issues of FE Online.
- ♦ Users who wish to search one or more issues of FE Online by author, title, keyword, and/or words in text.

Each of these categories can be best served by a different hierarchy of menus and files. Only the first type of user need be served initially, and that type will be well-served by simply listing files by volume, issue, and initial page number.

Priorities

These are our goals for the next six months:

1) Put all articles from one or more 1994 *FE* issues on the Internet before the December meeting of the Entomological Society of America.
2) Find a format superior to Postscript for posting *FE* articles on the Internet.
3) Find a suitable way to put March 1994 and earlier *FE* articles on the Internet.
4) Put all 1994 *FE* articles on the Internet.

SANFORD PORTER, CHAIRMAN; J. MCLAUGHLIN; P. PARKMAN

REPORT OF THE NECROLOGY COMMITTEE

Given below are the names of F.E.S. members and dear colleagues who have recently passed away, all of whom will be greatly missed:

Dr. K. C. Emerson of Sanibel, FL, world-renowned worker in chewing and sucking lice (Mallophaga and Phthiraptera);

Dr. G. B. Fairchild, long-time member of F.E.S. and a specialist in Diptera: Tabanidae;

Dr. H. R. Gross, long-time F.E.S. member;

Dr. F. R. Lawson, long-time F.E.S. member, and a researcher with USDA, ARS, on tobacco pest management, particularly concerning Hymenoptera;

Dr. A. Perdomo, F.E.S. member and resident in Central America;

Dr. J. A. Ramos, of Mayagues, Puerto Rico, a long-time member of F.E.S.;

Dr. R. E. Waites, long-time and very active F.E.S. member, who worked as Research Associate with Florida D.P.I., specializing in Coleoptera: Coccinellidae;

Dr. H. K. Wallace of Gainesville, FL, Professor Emeritus, Department of Zoology, University of Florida, and past-president of F.E.S. (1946), who specialized in spider biology, particularly with respect to Lycosidae and Salticidae;

Dr. S. R. Yokum, long-time and very active F.E.S. member, without whom our meetings will surely be greatly changed.

These minutes of the 77th Annual Meeting of the Florida Entomological Society were reviewed and approved by the 1994-95 Executive Committee and Committee Chairpersons on September 27, 1994.

HONORARY MEMBERS OF THE FLORIDA ENTOMOLOGICAL SOCIETY, 1993-94

H. A. Denmark
W. G. Eden
L. A. Hetrick
L. C. Kuitert
F. Mead
A. J. Rogers
A. G. Selhime
H. V. Weems
D. O. Wolfenbarger

EXECUTIVE COMMITTEE MEETINGS
1993-1994

5 October 1993, Lake Alfred
18 January 1994, Gainesville
12 April 1994, Lake Alfred
8 August 1994, Stuart

DAVID G. HALL
Secretary

PHOTOGRAPHS FROM THE 77TH ANNUAL FLORIDA ENTOMOLOGICAL SOCIETY MEETING, AUGUST 8-11, 1994 IN STUART

1

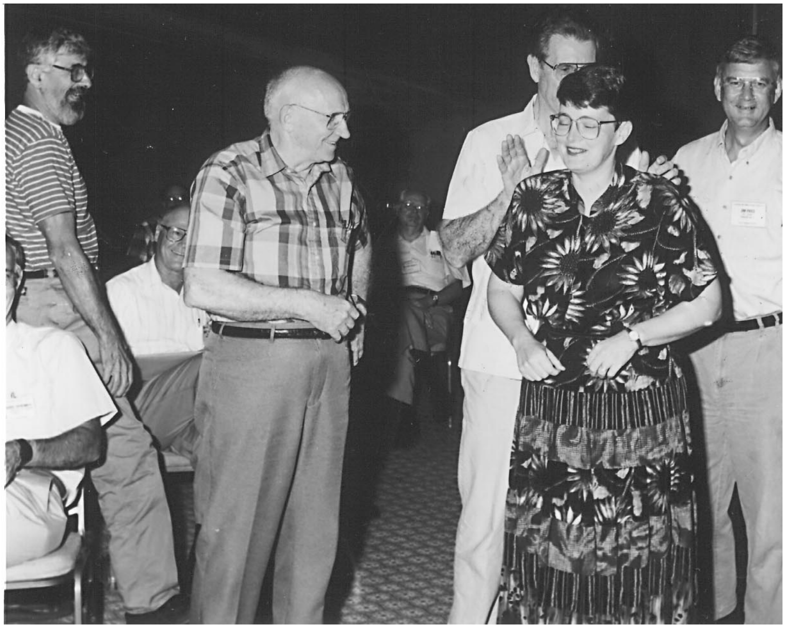

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Fig. 1. Incoming President Ellen Thoms is escorted to the podium by Past Presidents (left to right) Dale Habeck, Cliff Lofgren, Joe Knapp, and Jim Price. Fig. 2. Ernest -

ard Brenner.

3

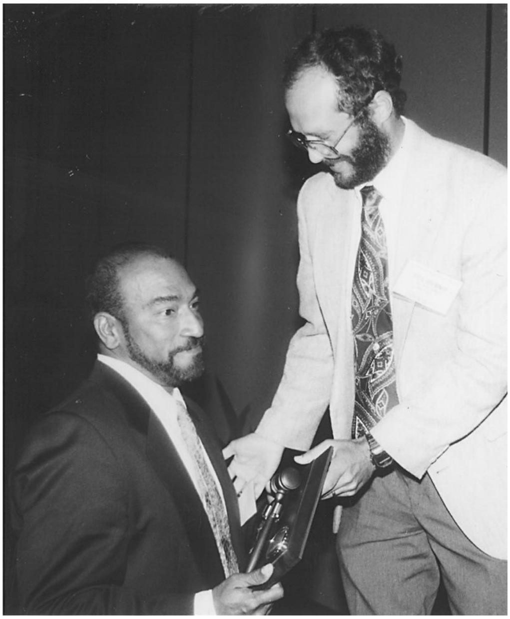

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Fig. 3. Outgoing President Jorge Peña (left) receives Outstanding Dedicated Service Award presented by Richard Brenner.

Fig. 4. The Annual Achievement Award for Research is presented to Robin Giblin-Davis.

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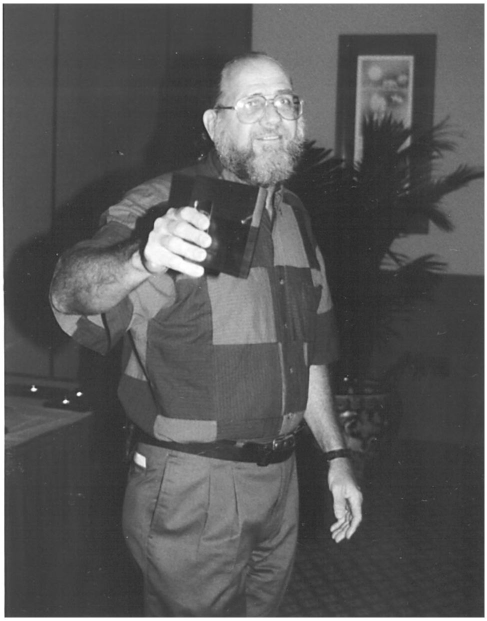

Fig. 5. Howard Frank receives the Presidential Recognition Award for organizing the Caribbean Directory of Entomologists and for co-organizing Behavioral Ecology Symposia for the period 1988 through 1994. Fig. 6. Charli
d

Industry.

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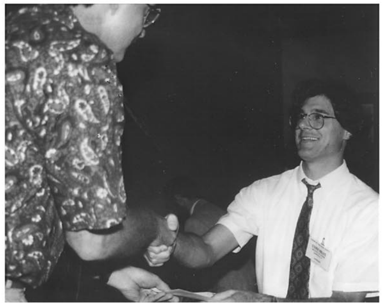
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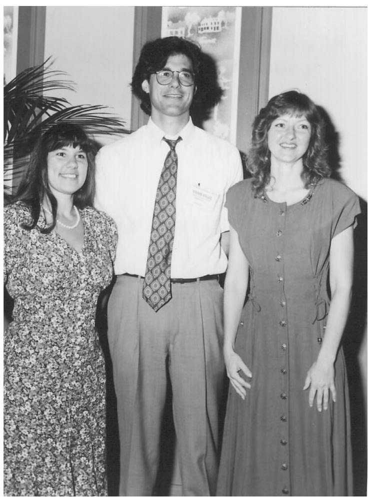

Fig. 7. Richard Brenner presents a Certificate of Appreciation to James Coffelt for planning and organizing the program for the 77th Annual Meeting.

Fig. 8. For service to FES as Chairman of the Local Arrangements Committee, George O'Meara receives a Certificate Of Appreciation.

Fig. 9. David Oi is recognized with a Certificate of Appreciation for assisting in organizing the program for the Annual Meeting.

Fig. 10. Steven Valles accepts FES Student Scholarship from Pat Parkman.

Fig. 11. Keynote Speaker May Berenbaum.

Fig. 12. Student Paper Contest winners (left to right) Marci Aparicio (Third Place), Steven Valles (Second Place), and Dini Miller (First Place).

THIRD INTERNATIONAL CARIBBEAN CONFERENCE OF ENTOMOLOGY AND 78TH ANNUAL MEETING OF THE FLORIDA ENTOMOLOGICAL SOCIETY

The Third International Caribbean Conference of Entomology (78th Annual Meeting of the Florida Entomological Society) will be held August 6-10, 1995, at the Carari Hotel, San Jose, Costa Rica. Registration forms and information will be mailed to members and have appeared in the Newsletter.

SUBMISSION OF PAPERS

The deadline for submission of papers for the 78th Annual Meeting of the Florida Entomological Society will be **Tuesday 10 May, 1995**. The meeting format will be similar to those in the past with eight minutes allotted for presentation of oral papers and two minutes for discussion. Confirmation of receipt of papers will be sent to the first author. There will be oral student paper sessions with awards as in previous years. A description of the format for judging the student papers has been printed in the Newsletter. Students participating in the judged sessions must be members of the Florida Entomological Society and registered for the meeting.

Russ Mizell, Chairman
Program Committee, FES
NFREC-MONTICELLO
P.O. Box 409L Monticello, FL 32344
Phone: (904) 342-0228
FAX: (904) 342-0230
Internet: RFM@GNV.IFAS.UFL.EDU