

SYSTEMATIC STUDIES OF NEW WORLD ENCARSIA SPECIES
AND A SURVEY OF THE PARASITOIDS OF BEMISIA TABACI
IN FLORIDA, THE CARIBBEAN AND LATIN AMERICA

By

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Chairperson: Dr. David J. Schuster
Major Department: Entomology and Nematology

Fifty-four species of the genus Encarsia, including the description of three new species, Encarsia lanceolata spec. nov., E. pseudocitrella, and E. polaszeki spec. nov.; 13 new distribution records; and 35 new host records are reported from the New World. The synonymy of E. hispida De Santis with E. meritoria Gahan is re-established, E. protransvena Viggiani is placed in synonymy with E. armata (Silvestri) and Encarsia alboscutellaris De Santis is transferred to the genus Encarsiella. Seventeen worldwide Encarsia species groups are recognized, 12 occur in the New World. Two new species groups, the Plaumannii and Porteri Groups, and 3 new subgroups of the Strenua Group, Strenua, Quercicola and Bella, are proposed.

Taxonomic keys and figures are given to the genera of parasitoids that attack aleyrodids, worldwide Encarsia species groups, and Encarsia species that parasitize aleyrodids in the New World. Each species group is diagnosed and individual Encarsia species that parasitize whiteflies in the New World are diagnosed and redescribed.

Results of a cladistical analysis of 15 Encarsia species, 2 Encarsiella species and Pteroptrix chinensis based on 40 morphological and 1 biological characters indicated a close relationship between the genus Encarsia and the genus Pteroptrix, and supported the transfer of Encarsia alboscutellaris De Santis to the genus Encarsiella.

Parasitoids were reared from the sweet potato whitefly (SPWF), Bemisia tabaci, and 37 other whitefly species in a survey conducted in Florida, the Caribbean and Latin America between 1988 and 1992. Nineteen and 12 parasitoid species were reared from the SPWF in the New World and Florida, respectively, including 3 new Encarsia species. Seasonal and geographic distribution and host records for each parasitoid species, and the parasitoid complex of the SPWF on various host plants and locations, are given.

CHAPTER 1

INTRODUCTION

The following study was initiated in response to the need to gather information on the identity and biology of native and exotic parasitoids of Bemisia tabaci (Gennadius). B. tabaci, also known as the tobacco, cotton or sweet potato whitefly, referred to from here on as SPWF, which has for many years been a serious pest in the Caribbean and Central American countries. Although it was recorded from Florida as early as 1894 (Quaintance, 1900), it was seldom a serious pest in the United States until outbreaks occurred in 1981 in the irrigated desert regions of the southwestern United States, causing an estimated \$100 million in agricultural losses (Duffus & Flock, 1982). Damages caused by the SPWF include reduction of crop yields by direct feeding injury and loss of host plant vigor; product contamination by honeydew and consequent production of sooty mold fungus; induction of growth disorders; and transmission of at least 19 different viruses (Osborne, 1992). In 1986, the Florida greenhouse foliage industry experienced severe population outbreaks of the SPWF on poinsettia plants (Price 1987) that resulted in statewide losses in excess of \$2 million (Osborne, 1992).

Squash silverleaf and tomato irregular ripening were observed as widespread outbreaks of SPWF occurred on Florida field vegetable crops in 1987 and 1988 (Maynard & Cantliffe, 1989). These new disorders were attributed to the association of SPWF on these crops (Schuster et al. 1990; Yokomi et al. 1990). Losses due to irregular ripening, gemini virus, and increased control costs on tomatoes alone in Florida were estimated at \$125.3 million (Schuster, 1992). Ornamental growers in Florida were forced to abandon some crops and increase pesticide applications on many others; tomato growers sprayed as often as twice a week for SPWF. Peanut yields were reduced in some fields to only one-third of that of previous years due to heavy SPWF infestations (Leidner, 1991). Annual losses to all Florida agriculture were conservatively placed at \$141 million (Schuster, 1992). Large populations of SPWF were reported on cotton grown in the Texas Rio Grande Valley in 1991 causing an estimated loss of \$80 million (Faust, 1992). Epidemic outbreaks were reported on cotton, melons, lettuce and other crops in the Imperial Valley, California and in Arizona (Gill, 1992). Large populations of SPWF occurred on the sesame crop in Venezuela and on tomatoes in the Dominican Republic and Honduras and other countries resulting in heavy crop losses (F.D. Bennett, personal communication). The total losses caused by the SPWF to U.S. agriculture in 1991 was estimated at least \$500,000,000 (Perring et al. 1993).

The rapid rise of the SPWF to key pest status has been attributed to the widespread use of pesticides and changes in crop culture in the early 1970's. This

led to the SPWF's accelerating development of physiological resistance to pesticides and the disruption of its natural enemy fauna (Byrne et al. 1990). Resistance of the SPWF to various pesticides has been documented by Prabhaker et al. (1985) and others.

Perring et al. (1992) suggested that the sudden change in the pest status of the SPWF was due to the invasion of a new, but morphologically similar species to which the common name, "the silverleaf whitefly" was given. Populations of the "silverleaf whitefly" have a wider host range, varying ability to transmit viruses, and different biochemical markers, and are reproductively incompatible with laboratory colonies of the historically "indigenous" (pre-1986), cotton-derived SPWF populations.

In 1987, Florida biological control and plant protection specialists, virologists and pathologists, growers and grower groups, together with scientists from Arizona, California and Texas, initiated a multi-faceted Bemisia research program. The program focused on developing alternative control and management measures to suppress SPWF populations to acceptable economic levels. Conservation and introduction of biological control agents were key elements of the overall integrated pest management strategy. Parasitoids have played an important role in the control of several whitefly pest species (Table 1.1). A statewide survey of the natural enemies of the SPWF was initiated in 1988 to gather information on the parasitoid complex of the SPWF in Florida and the humid neotropics, and to identify promising natural enemy species from the neotropics (and other areas of the

Table 1.1. Parasitoids used for the biological control of whitefly pests species.

Whitefly species	Parasitoid species	Reference
<u>Aleurocanthus woglumi</u>	<u>Amitus hesperidum</u> <u>Encarsia opulenta</u> <u>E. merceti</u> <u>E. clypealis</u> <u>E. smithi</u> <u>Eretmocerus serius</u>	Flanders 1969.
<u>Aleurothrixus floccosus</u>	<u>Cales noacki</u>	Rose and Woolley, 1984
<u>Dialeurodes citri</u>	<u>Encarsia lahorensis</u>	Nguyen and Sailer, 1979
<u>Parabemisia myricae</u>	<u>Encarsia transvena</u>	Rose et al. 1981
	<u>Eretmocerus debachi</u>	Rose and Rosen, 1992
<u>Siphonius phillyreae</u>	<u>Encarsia partenopea</u>	Gould et al. 1992
<u>Tetraleurodes sp.</u>	<u>Cales noacki</u>	Rose and Woolley, 1984
<u>Trialeurodes vaporariorum</u>	<u>Encarsia formosa</u>	Osborne, 1981

world) for eventual introduction into Florida and the southern United States. The objectives of the survey were to identify the species of parasitoids commonly found parasitizing SPWF; measure the ratio between emergent SPWF and parasitoids as a comparative indicator of parasitism; identify important SPWF wild host plant reservoirs; identify changes in the parasitoid complex composition attributable to seasonal, geographic and host plant variation; determine if SPWF and its parasitoids can overwinter in northern Florida. In addition, parasitoids were reared from several other whitefly species in order to determine the host range for each of the parasitoid species reared from SPWF (Bennett et al. 1990).

Previous surveys of parasitoids of SPWF have been carried out in Pakistan by Dr. A. I. Mohyuddin of the International (formerly Commonwealth) Institute of Biological Control (IIBC), and in Africa and the Middle East by Prof. D. Gerling (University of Tel Aviv, Israel). Results of these have been largely published (Lopez-Avila 1986; Gerling, 1985; Rivnay and Gerling, 1987) but contain some errors. Thanks to the accumulation of a large amount of reliably reared material specimens from SPWF by F. D. Bennett, as well as the opportunity to examine the rich material from the IIBC survey, many of these errors were corrected by Polaszek et al. (1992).

The present study is divided in two parts. The first part is a taxonomic review of the species of Encarsia described from the New World along with the description of three New World species. Also included are biological information, references and a key for the following genera of primary and secondary whitefly parasitoids: Azotus, Cales, Dirphys, Eretmocerus, Encarsiella (Aphelinidae); Amitus (Platygastridae); Euderomphale (Eulophidae); Metaphycus (Encyrtidae); and Signiphora (Signiphoridae). The key that is presented for the Encarsia species of the New World includes the species that were described from areas outside the survey area but whose distribution includes the New World. Host, distribution and biological information for these species are also presented.

The second part of this study examines the population dynamics of the SPWF and its parasitoid complex on different host plants and in different localities in Florida. In addition, data are presented on the distribution and relative abundance of parasitoids reared from SPWF in other countries.

Several obstacles had to be overcome, particularly during the earlier phases of the survey. Taxonomically, the genus is not very well understood, especially in the New World. Systematic knowledge of the genus in the United States has remained dormant for more than 50 years, with the exception of work done on the biology and utilization of a limited number of Encarsia species. Most of these species were introduced for the biological control of specific whitefly and scale pests. Initially, it was necessary to seek the assistance of Dr. Andrew Polaszek (Natural History Museum, London), one of the few experts on the taxonomy of this genus in the world. The genus Encarsia is considered to be a taxonomically difficult genus for several reasons. The minute size of the organisms, which rarely exceed one millimeter in length, usually necessitates that they be cleared of their body content and mounted on microscope slides in order to observe the characters that are used to distinguish them from other species. Only a small portion of the New World Encarsia species are probably known at present. Of the more than 170 described species worldwide (Hayat 1989), only thirty-six species (currently valid) have been described from the New World (Table 1.2). Fifteen exotic species have been reported in the New World. Most of these species are of Oriental origin that were introduced as biological control agents for specific whitefly and scale insect pests (Table 1.3). This survey adds 3 new species and 3 new distribution records for exotic species to increase the number of New World species to fifty-four.

Distribution and host range information for the New World Encarsia species is very

Table 1.2. Encarsia species described from the New World.

Species	Author	Year	Country	Host
alboscutellaris	De Santis	1979	Argentina	?Aleyrodidae
americana	DeB. & Rose	1981	Mexico	Aleyrodidae
aurantii	Howard	1894	USA: CA	Diaspididae
basicincta	Gahan	1927	Puerto Rico	Aleyrodidae
bella	Gahan	1927	USA: MI	Diaspididae
berlesei	Howard	1906	USA: DC	Diaspididae
brasiliensis	Hempel	1904	Brazil?	Aleyrodidae
brunnea	Howard	1908	Puerto Rico	Aleyrodidae
catherinae	Dozier	1933	Haiti	Aleyrodidae
ciliata	Gahan	1927	Puerto Rico	Aleyrodidae
citrella	Howard	1908	USA: FL	Aleyrodidae
citrina	Howard	1891	USA: CA	Diaspididae
coquillettii	Howard	1908	USA: CA	Aleyrodidae
cubensis	Gahan	1931	Cuba	Aleyrodidae
desantisi	Viggiani	1981	Argentina?	Aleyrodidae
ectophaga	Silvestri	1938	Argentina	Diaspididae
elongata	Dozier	1937	USA: LA	Diaspididae
formosa	Gahan	1924	USA: ID	Aleyrodidae
gallardoi	Marelli	1933	Argentina	Aleyrodidae
guadaloupae	Viggiani	1985	Guadeloupe	Aleyrodidae
haitiensis	Dozier	1932	Haiti	Aleyrodidae
lopezi	Blanchard	1940	Argentina	Aleyrodidae
luteola	Howard	1895	USA: DC	Aleyrodidae
lycopersici	De Santis	1957	Argentina	Aleyrodidae
meritoria	Gahan	1927	USA: FL	Aleyrodidae
nigricepsphala	Dozier	1937	Puerto Rico	Aleyrodidae
peltata	Cockerell	1911	USA: CO	Aleyrodidae
pergandiella	Howard	1907	USA: DC	Aleyrodidae
perniciosi	Tower	1913	USA: MA	Diaspididae
peruviana	Rust	1913	Peru	Diaspididae
plaumanni	Viggiani	1987	Brazil	?Aleyrodidae
porteri	Mercet	1927	Chile	Aleyrodidae
portoricensis	Howard	1907	Puerto Rico	Aleyrodidae
protransvena	Viggiani	1985	USA: FL	Aleyrodidae
quaintancei	Howard	1907	USA: DC	Aleyrodidae
quercicola	Howard	1908	USA: CA	Aleyrodidae
townsendi	Howard	1907	Mexico	Aleyrodidae
variegata	Howard	1908	USA: FL	Aleyrodidae

Table 1.3. Extralimital Encarsia species occurring in the New World.

Species	Author	Year	Country	Host
armata	Silvestri	1927	Vietnam	Aleyrodidae
clypealis	Silvestri	1928	Vietnam	Aleyrodidae
diaspidicola	Silvestri	1909	South Africa	Diaspididae
divergens	Silvestri	1926	Singapore	Aleyrodidae
fasciata	Malenotti	1917	Italy	Diaspididae
inaron	Walker	1839	U.K.	Aleyrodidae
lahorensis	Howard	1911	Pakistan	Aleyrodidae
lounsburyi	Paoli & Berl.	1916	Italy	Diaspididae
lutea	Masi	1909	Italy	Aleyrodidae
merceti	Silvestri	1926	Singapore	Aleyrodidae
opulenta	Silvestri	1928	China	Aleyrodidae
sankarani	Hayat	1989	India	Diaspididae
smithi	Silvestri	1926	China	Aleyrodidae
strenua	Silvestri	1927	Macao	Aleyrodidae
transvena	Timberlake	1926	USA: Ha	Aleyrodidae

limited. Such information could provide clues for species determination and utilization.

Eleven of the 16 species that were described from the United States were collected in California, Florida, or Washington, D. C. Only 2 species have been described from Mexico; 8 of the 10 South American species were described from Argentina or Brazil; and 5 of the 9 Caribbean species were described from Puerto Rico.

Many of the species descriptions lack sufficient detail to allow the species to be distinguished from similar species. Species identification often necessitates that specimens be compared with those of the type series or at least reference specimens identified by an expert on the group. Most species are only known from the type specimen or type series. This precludes the ability to determine what intraspecific variation exists in the species. Often it is difficult or impossible to observe the finer morphological details that can be useful in distinguishing closely related species in specimens from the type series. Many specimens are nearly 100 years old and were not properly cleared before mounting them in Canada balsam. Some specimens may show artifacts resulting from the mounting process or the mounting medium used. Antennal segments may be longer or wider and colors less pronounced in preserved specimens than in fresh ones.

The presence of cryptic species in the family Aphelinidae is well known and is a major concern in the identification of Encarsia species. Slight differences in morphological characters may represent intraspecific variation or may be indicative of a morphologically similar but distinct species. DNA analyses or detailed morphological examination of a long series of a species representing different habitats and environmental conditions may give some insight to the species identity. However, for biparental species, the question is better addressed by conducting reproductive crosses of isolated individuals as was done by Rao and DeBach (1969) for species in the genus Aphytis (Aphelinidae).

Morphological characters of male Encarsia are sometimes useful in species or species group determination. However, in several species, males are not known. Males do not exist in the uniparental species that reproduce parthenogenetically. Obviously, it is impossible to use reproductive isolation as a means for discriminating cryptic species in uniparental species. In other species, males probably occur but have not been collected. Production of males has been induced in some thelytokous species by the ingestion of antibiotics or exposure to higher temperatures. Theoretically, these treatments kill or inhibit the endosymbiotic bacteria found in the reproductive tract of the female that prevent the development of the male gametes (Zehori-Fein et al. 1992).

Males of many Encarsia species develop as hyperparasites on females of their own species or on a different species present in the host insect species. Therefore, positive association of males and females of the species reared from the same sample may be dubious. Considering the importance of Encarsia species in the biological control of whiteflies and the increasing number of species currently being introduced against the SPWF, it was imperative that the earlier described species be studied not only to establish their correct identities, but also to avoid the unnecessary creation of invalid synonyms.

CHAPTER 2

BIOLOGY AND POPULATION STUDIES

2.1. Whiteflies

2.1.1. Geographic Distribution

There are about 1,200 described species of whiteflies (Mound & Halsey, 1978). The majority of these species are tropical in origin, where about 724 species have been described versus about 420 from temperate regions. Strong et al. (1984) found that the number of species of whiteflies in Europe was correlated with latitude, ranging from 3 species in northern Sweden to 32 species in southern Spain.

2.1.2. Systematics and Evolutionary Relationships

The family Aleyrodidae is most closely related to the Psyllidae, which, along with the Coccoidea and Aphidoidea, forms the Sternorrhyncha in the order Homoptera. There are 126 genera of aleyrodids within the two subfamilies that have been designated. The Aleurodicinae, comprised of 17 genera and about 100 mainly Neotropical species, is considered to be the more primitive of the two

subfamilies; the Aleyrodinae, to which all other species are assigned, is cosmopolitan in distribution. The phylogenetic relationships between the genera of the family are not well understood; there is even some doubt as to validity and evolutionary significance of some of the characters that have been used to separate the two subfamilies.

2.1.3. Life Stages

Whiteflies have six life stages: the egg, the crawler (1st nymphal instar or stadium), two sessile nymphal instars (2nd and 3rd instar), the "pupa" (4th instar), and the adult or imago. The terms " nymphal" and "larval" have been used interchangeably in the literature to denote the immature forms. The fourth instar is not a true pupa because feeding occurs during the first part of this stage and transformation into the adult takes place in the first part without a "pupal" moult. The term "nymph" will be used to denote the first three immature stages, and the term "pupa" will be utilized to denote the last immature stage.

2.1.4. Sex Ratio

Gameel (1978) reported the sex ratio of 1:1 for the SPWF on cotton and Van Lenteren and Noldus (1990) have reported similar sex ratios for *Trialeurodes vaporariorum*. The sex ratio of the SPWF is sufficiently variable to preclude generalization (Butler et al. 1986; Gerling et al. 1986). Horowitz and Gerling (1992) found that the sex ratio of the SPWF ranged from a female-biased condition early

in the season to male biased at summer's end on cotton in Israel. Their study showed that young females laid proportionately more female-producing eggs than older females. Like most whiteflies, the SPWF is arrhenotokous, females can regulate the sex of their progeny as long as they have a sufficient sperm supply. Mated females can lay both haploid (male) or diploid (female) eggs, whereas unmated females lay only haploid (male) eggs.

2.1.5. Developmental Rate

Developmental rate, fecundity, longevity and mortality of whiteflies may vary with temperature, relative humidity, rainfall and host plant (Table 2.1). Favorable conditions for SPWF development include high temperature, low humidity, periods of no or low rainfall and mild winters (Jagdev & Butler, 1985). Lower and upper threshold temperatures for development are 10 and 32°C, respectively. Although the SPWF may develop faster (17 days) at 30° C, it appears that 27°C (25-50 days) is a more optimal temperature for overall whitefly population development; longevity and fecundity of the SPWF decrease at the higher temperatures (Ozgur et al. 1986). Hendi et al. (1987) reported the following developmental rates (days) for SPWF instars on tomatoes (30°C and 5% RH): preoviposition (1-2), 1st instar (2-4), 2nd instar, (2-4), 3rd instar (2-4), and pupa (6). Zalom and Natwick (1987) reported that the SPWF had seven to nine generations per year in the southwestern United States. They determined the number of degree days the SPWF required to complete its development in field cages (degree-days) as eggs

Table 2.1 Developmental time (days) of *Bemisia tabaci* reared at different temperatures on various host plants.

Temperature (°C)	Host	Dev. time	Reference
16.8	cotton	68	Coikesen et al. 1987
21.3	cotton	36	
25	cotton	24.2	
14.9	cotton	65.1	Butler et al. 1983
30.0	cotton	16.6	
27	cotton	25-50	Ozgur et al. 1986
30	cotton	17	
30.0	tomato	21	Hendi et al. 1987.
24.1 RH=70%	bean	28.3	Eichelkraut 1986
25.3 RH=69.8%	bean	25.3	

(27), nymphs (268.5) and pupae (73); the average generation time was achieved at 369.5 degree-days.

Developmental rate may differ for different host plants (Table 2.1) or varieties. (Boica & Vendramin 1986). Overall population development may depend on the characteristics of the leaf surfaces of the host plant. Pubescent leaf and closed- canopy cotton varieties were reported to be much more heavily infested than glabrous, smaller-leaf, open-canopy varieties (Ozgur et al. 1986). Moderate pubescence seems preferable as it provides a physical barrier to natural enemies and a favorable microclimate.

2.1.6. Fecundity

Fecundity is highly variable and may be influenced by plant host species, cultivar, physiological state of the host plant, temperature and humidity. Ogzur et al. (1986) reported that fecundity of the SPWF varied from 80 to more than 300 eggs per female on cotton in the Sudan. Butler et al. (1983) found that the average number of eggs per female SPWF on cotton was 81 and 72 at 26.7 and 32.2°C, respectively. Van Lenteren and Noldus (1990) reported that *T. vaporariorum* fecundity was constant from 18 to 27°C but decreased at lower and higher temperatures. They also reported higher fecundity rates for *T. vaporariorum* reared on eggplant versus that for those reared on cucumber, tomato or sweet pepper. The ovipositional rate is age-dependent, gradually increasing during the first days, reaching a plateau shortly before the female dies.

2.1.7. Longevity

Longevity of adult whiteflies varies on different host plants and at different temperature and relative humidity regimes but may also vary on the same host plant. SPWF adults lived 10 to 15 days in the field during summer temperatures (around 28°C) and 20 to 60 days in winter (around 15°C) (Gerling, Horowitz and Baumgartner, 1986). Adult lifespan was 8 to 43 and 17 to 27 days, for SPWF males and females, respectively.

2.1.8. Mortality

Both abiotic and biotic factors affect SPWF mortality (Figure 2.1). Abiotic factors include temperature, relative humidity, wind, and rain; biotic factors include parasitoids, predators, pathogens, and host nutrition. Unfavorable levels of temperature, humidity and rainfall are the most important mortality factors in crawler and first instar SPWF nymphs. Parasitization is the most important mortality factor during the advanced nymphal stages (Horowitz et al. 1984). The degree of mortality to immature stages may vary on different host plants, and even on the same host plant. Lenteren and Noldus (1990) found that pre-adult mortality of *T. vaporiorarum* was much higher on sweet pepper than on tomato, cucumber or eggplant. Hendi et al. (1985) observed high natural mortality (64.4 to 97.5%) of SPWF on tomatoes in Egypt.

2.1.9. Host Plant Specificity, Suitability and Preference

There have been over 500 hosts recorded for the SPWF from 74 families of crop and weed species. Van Lenteren and Noldus (1990) pointed out the distinction that needs to be made between a preferred host species and a suitable host species. Whiteflies often develop faster, have lower immature mortality and higher fecundity rates on a preferred host or variety than on a suitable host. Host plant suitability can be affected by the addition of nitrogen fertilizers (Onillon et al. 1986).

2.1.10. Migration

SPWF adults demonstrate two distinct flight patterns. Short-distance flight occurs under the plant canopy. Newly emerged adults leave the lower leaves from which they emerged and move to the upper leaves to feed and oviposit. Long-distance flight, sometimes called the dispersal phase, occurs when adults take off from their host plant, get caught in an air current and drift passively, sometimes for several miles. Temperature and light thresholds affect the number of SPWF adults taking flight (Bellows et al. 1988). SPWF populations are considered to be continuously mobile in areas where a variety of host plants are consistently available. Intensification of agriculture and off season production of new suitable host plants of the SPWF provide bridges between cotton seasons and may lead to the current increased pest status (Coudriet et al. 1985).

2.1.11. Population Dynamics

Many biotic and abiotic factors affect the population dynamics of the SPWF. Temperature typically affects fecundity, mortality and developmental rates; rainfall and relative humidity are other important abiotic factors. Nutritional content, development and physical characteristics of the host, availability of alternate hosts, natural enemies (predators, parasitoids and fungi) and man's activities through the use of cultural, chemical and other control practices also play important roles in the overall population dynamics of the whitefly.

2.2. Parasitoids

The genus Encarsia belong to the Aphelinidae, a small-sized family of the chalcidoid Hymenoptera. There are about 175 described species of the genus Encarsia (Hayat 1989). The majority of Encarsia species are parasitoids of whiteflies, but several are parasitoids of diaspine scales and a few have been reared from other hosts, such as from Lepidoptera eggs. The genus is more highly represented in the Palearctic and Oriental region where more species have been described. However, the disparity in the number of species in the Orient versus other regions of the world may be due, in part, to the greater effort that has been made, primarily by Viggiani and Hayat, in documenting the fauna of that region, versus little effort that has made in the other regions.

2.2.1. Life Cycle and Development

Some Encarsia species are uniparental, but the majority are biparental. Mated females can lay both fertilized diploid eggs that become females, and unfertilized haploid eggs that become males. Female eggs are usually laid in the haemocoel of aleyrodid and diaspine scale insect hosts and develop into primary endoparasitoids. In most of the biparental species that have been studied, the male eggs are laid on the outside of the body of the larval female primary parasitoid. The males develop as hyperparasites on females (or males) of their same species (adelophoparasitoid) or on a different parasitoid species in the host insect. Females of E. smithi may develop either as primary parasitoids of the citrus

blackfly or as hyperparasitoids of *E. opulenta* (Ru & Sailer 1987). The production of males and females may be affected by the availability of mates and suitable hosts, and the action of symbiotic bacteria in the reproductive tract of the females that inhibit the production of male gametes (Godfray & Hunter, 1993). Also, Wilson and Woolcock found that sex was determined in *Ooencyrtus submetallicus* (Encyrtidae) by the temperature to which the females were exposed. Females are synovigenic. Eggs are produced in two ovaries, each composed of three ovarioles. The eggs develop and mature continuously throughout the female's lifespan but most are laid during the first few days after emergence. Fecundity in *Encarsia* species may be highly variable, depending upon the parasitoid species, temperature, relative humidity and host nutrition. Fecundity data for several species of *Encarsia* are given in Table 2.2.

Table 2.2. Fecundity of six *Encarsia* species and *Eretmocerus mundus*.

Species	Temp°C	eggs/♀	Reference
<i>E. formosa</i>	17	165.6	Vet and van Lenteren, 1981
<i>E. formosa</i>	25	442.2	Arakawa, 1982
<i>E. inquirenda</i>	22-26	20.6	Gerson, 1968
<i>E. lahorensis</i>	26	20-50	Viggiani, 1984
<i>E. luteola</i>	25	63	Gerling et al. 1987
<i>E. luteola</i>	22-30	57.8	Gerling et al. 1987
<i>E. meritoria</i>	17	85.4	Vet and van Lenteren, 1981
<i>E. pergandiella</i>	26.6	47	Gerling, 1985
<i>E. pergandiella</i>	?	48.5	Viggiani, 1984
<i>E. pergandiella</i>	17	124.9	Vet and van Lenteren, 1981

Encarsia species pass through three larval instars. The first and second instars have no functional spiracles. The third instar has open, functional spiracles and voids its meconia before moving on to the prepupal and pupal phases. The position of the meconia in the host body can differ for different species. For

Table 2.3. Developmental time (days) of nine Encarsia species and Eretmocerus mundus.

Species	°C	Egg	Larva	Pupa	Total	References
<u>E. deserti</u> ♀	25	3	-	-	11-13	Gerling et al. 1987
<u>E. formosa</u> ♀	24	-	-	-	15	Gerling, 1983
<u>E. inquirenda</u> ♀	20	-	-	-	62.3	Gerson, 1968
<u>E. inquirenda</u> ♀	28	-	-	-	26.3	Gerson, 1968
<u>E. lahorensis</u> ♀	24	-	-	-	24.5	Ru & Sailer, 1979
<u>E. lahorensis</u> ♂	24	-	-	-	12-15	Ru & Sailer, 1979
<u>E. lahorensis</u> ♀	25	3	8-17	7-8	20-28	Viggiani, 1978
<u>E. lahorensis</u> ♂	25	3	9-12	7-9	19-24	Viggiani, 1978
<u>E. lutea</u> ♀	25	4	8	6	13-18	Gerling & Foltyn, 1987
<u>E. lutea</u> ♂	25	4	7	5	14-15	Gerling & Foltyn, 1987
<u>E. lutea</u> ♀	-	-	-	-	15	Vet and Lenteren, 1980
<u>E. lutea</u> ♀	15	-	16.1	6.2	22.3	Abdel et al. 1987
<u>E. lutea</u> ♂	15	-	25.6	14.8	40.4	Abdel et al. 1987
<u>E. lutea</u> ♂	28	-	8.8	5.7	14.5	Abdel et al. 1987
<u>E. meritoria</u> ♀	12	-	-	-	75.0	Avilla et al. 1991
<u>E. meritoria</u> ♀	28	-	-	-	11.0	Avilla et al. 1991
<u>E. pergandiella</u> ♀	24	3	7	5	15	Gerling, 1966
<u>E. pergandiella</u> ♂	24	+	9	4-5	14	Gerling, 1966
<u>E. quaintancei</u>	-	-	-	-	10-25	Dysart, 1966
<u>E. transvena</u>	-	-	-	-	12.9	Kapadia & Puri, 1990
<u>Eretmocerus mundus</u> ♀	-	-	-	-	16.6	Kapadia & Puri, 1990
<u>Eretmocerus mundus</u> ♀	25	-	10.5	10	20.5	Foltyn & Gerling, 1985

species in which the males develop as hyperparasites, the first instar male larvae develop inside the hymenopterous host and the second instar exits the host and develops to maturity as an ectoparasitoid. The developmental rate of males may be equal to or shorter than that of the female. Females may all emerge within a few days, or have their emergence spread out over one to two weeks. This assures insemination of females even in small, isolated host populations (Gerling et al. 1987). Hunter (1989) found that hyperparasitic male E. pergandiella developed faster on 9-day-old (pupal) E. pergandiella females than on 7-day-old females. Data suggested that single release colonization is likely to be limited by a delay of 7 to 9 days between the oviposition of female eggs and suitability of these females for oviposition of male eggs. As males take an additional 15 to 16 days to develop, the total time elapsed between the time when colonizing females lay eggs and the first mating of F1 female progeny is 22 to 25 days.

The duration of the developmental period is linked to climatic factors and to the condition of the host. The rate of parasitoid development depends primarily on temperature and is usually shorter for males (Table 2.3). Female E. pergandiella (24°C) develop in 15 days and males in 13 to 14 days. (Gerling, 1966). Avilla et al. (1991) reported that E. meritoria females completed their life cycle in 11 days at 28°C and in 75 days at 12°C. Flanders (1960) found that at constant temperature (80°F), E. perniciosi completed its life cycle in about 30 days if eggs were deposited in the first-instar host, 18 days if they were deposited immediately before the host scale was half grown, and 26 days if they were deposited after the host was half grown. Development may be highly variable for

different *Encarsia* species. *E. transvena* developed in an average of 12.9) days (Kapadia & Puri, 1990), while most other species complete their development in 15 and 25 days (Table 2.3).

2.2.2. Longevity

Adult longevity is dependent primarily upon reproductive physiology, available food, temperature and humidity. Greatest longevity was recorded for *E. formosa* (99 days at 15-16°C) and *E. deserti* (=*luteola*) (84 days) (Gerling, 1992). Most whitefly species are tropical or subtropical in origin and do not have a winter diapause, but their development slows and their populations decrease during the cooler or drier months. Those that overwinter do so in preimaginal stages. In Israel, *E. lutea* overwinters on SPWF nymphs on *Lantana* and other weed species. (Gerling, 1984). *E. lahorensis* females oviposit in diapausing stages of *Dialeurodes citri*; the egg hatches but the first instar larva does not develop into the second instar until its host has resumed activity and has become partially inflated (Viggiani 1984). Summer survival may vary greatly since it involves intensive host-associated activities such as searching and ovipositing. Gerling (1990) considers the "effective longevity", that time during which the females lay most of their eggs, to be a more meaningful parameter for understanding reproductive strategies than are total longevity. Synovigenic whitefly parasitoids have been found to complete their effective longevity in less than 20 days at temperatures above 20°C.

2.2.3. Host Feeding

Host feeding by parasitoids on whitefly immatures has been reported for E. formosa (Gerling, 1966), E. pergandiella (Gerling 1966b), E. opulenta (Dowell et al. 1981), E. deserti, E. transvena and E. lahorensis (Gerling, 1990) and probably is a common occurrence. The female thrusts her ovipositor through the nymph's body and laps up the exudate. Host feeding has been found to increase longevity and promote oogenensis (fecundity) in Encarsia females and may be an important mortality factor, especially in younger whitefly instars. Arakawa (1982) reported that each female E. formosa is able to kill an average of 423.7 and 101.3 host by parasitization and host feeding, respectively, for a total of 534 hosts attacked. DeBach (1943) reported up to 56% host mortality caused by feeding of Metaphycus helveolus (Compere) on black scale, Saissetia oleae (Bern.). The number of scales killed by host-feeding, which was largely when the scales were rather small for parasitization, was much greater than the number killed by parasitization. The relative importance of host-feeding was greater during the early phases of an infestation, whereas that of parasitization is higher later, as the scales increased in size. The value of parasite predatism is affected by the relative abundance of the host and parasite. Higher levels of host-feeding occur at lower host's density and with an increase in proportion of host below the size suitable for parasitism (Flanders 1953). Bartlett (1964) found that Microterys flavus (Howard) mutilated Coccus hesperidum L. scales when host-feeding was initiated but the host did not bleed freely. Host-feeding tendencies developed in individuals

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which later hyperparasitize *Eretmocerus* individuals inside SPWF nymphs (Gerling, 1983). *E. tricolor* females were reported to preferentially hyperparasitize female *E. inaron* rather than their own species. *E. opulenta* preferentially hyperparasitizes whiteflies containing *Amitus* females (Dowell et al. 1981). Females are able to distinguish between hosts parasitized by conspecifics but not those parasitized by other species. Some *Encarsia* species may develop as tertiary parasitoids of males of their own species or different species, creating a very complex ecosystem (Figure 2.2).

2.2.5. Adelphoparasitism

Various authors have speculated on the evolutionary significance of adelphoparasitism in the Aphelinidae. Hassell et al. (1983) showed that theoretically adelphoparasitism confers stability on the host-parasitoid dynamics. Walter (1988) argued that male heteronomous aphelinids have host relationships that differ from those of their conspecific females. In an ancestral species, deposition of female eggs became uncoupled, in terms of behavior, at oviposition, from the deposition of male eggs. During the evolution of heteronomous host relationships, males and females would have been subject to different selection pressures. As a result, males must have become adapted to their hosts independently of females becoming adapted to theirs. Godfray et al. (1992) stated that in general the observed sex ratio will be strongly correlated with the relative abundance of parasitized and non-parasitized hosts. If the hosts are rare, search

time will limit reproductive success, and the female will lay a male or female egg when she finds a host. Lifetime fitness is maximized by parasitizing all suitable hosts that are encountered.

2.2.6. Population Dynamics

Several studies have examined the dynamics of the SPWF parasitoid complex in different regions of the world. Puri et al. (1990) reported that E. transvena and Eretmocerus mundus were the primary parasitoids of SPWF on cotton in India. Maximum parasitization (54.6%) was reported during the more humid months of the year. E. lutea and Eretmocerus mundus are the major SPWF parasitoid species in the Sudan. Izaguirre (1993) found that E. pergandiella made up 51 to 87% and E. nigricephala 5 to 38 % of the SPWF parasitoid fauna on beans in Honduras. Interestingly, Eretmocerus only represented a maximum of 4% of the total parasitoids collected from various climatic areas during the two-year study. Gerling (1966) reported on the bionomics of the parasitoid complex of Trialeurodes abutiloneus and B. tabaci on cotton in California.

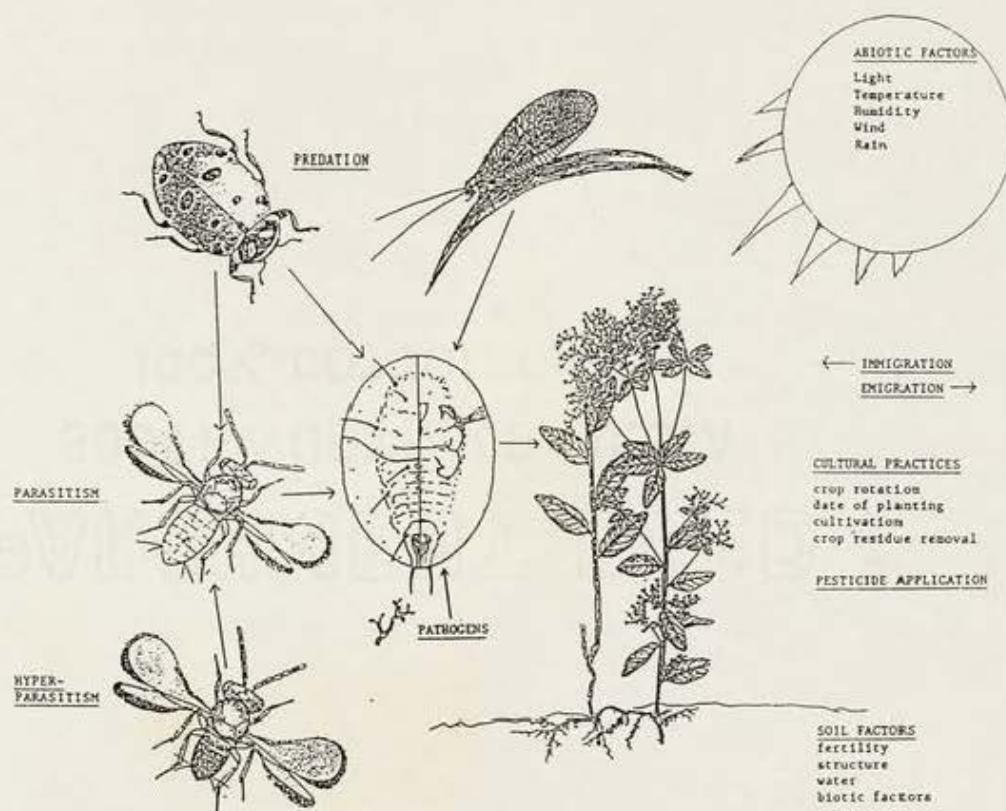


Figure 2.1. Factors affecting the development and mortality of the SPWF.

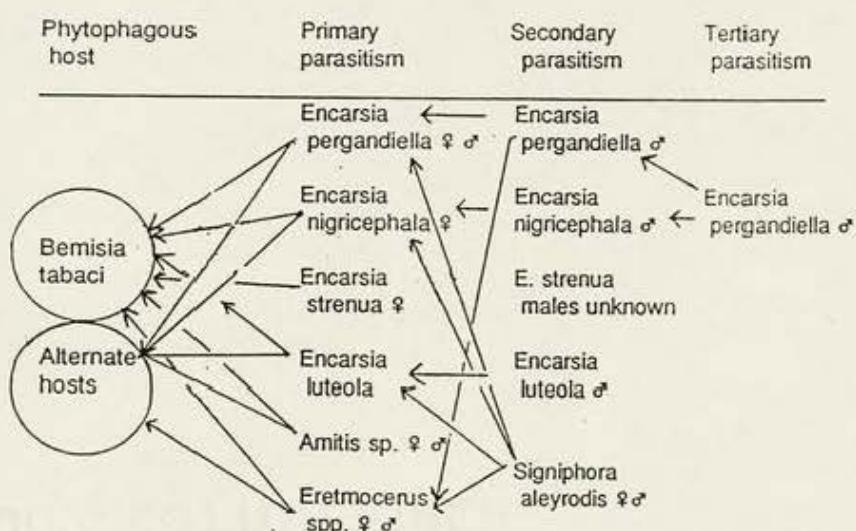


Figure 2.2. Intra- and interspecific relationships of parasitoids of the SPWF.

CHAPTER 3

HISTORICAL REVIEW AND HIGHER CLASSIFICATION

3.1. Introduction

The genus Encarsia belongs to the Aphelinidae, a small-sized family of the chalcidoid Hymenoptera, containing forty-nine valid genera (Hayat 1985) and approximately 860 species. Morphologically, the Aphelinidae show affinity to both the Eulophidae and the Encyrtidae, and have in the past been placed as a subfamily of each one of them in the past (Ashmead, 1904; Peck, 1951; Burks, 1967; Riek, 1970). Most aphelinid genera resemble the Eulophidae in the structure of the mesonotum (parapsidal grooves complete, axillae advanced into the base of the parapsides) and in the small number of antennal segments. Other genera, especially Coccobius, Marietta and Eutrichosomella, resemble the Encyrtidae in the shape of the mesopleura, in the large saltatorial mid-tibial spur, and in the presence of a well-developed strigil on the foreleg. Peck et al. (1964) regarded the family as a transitional taxon between the Eulophidae and the Trichogrammatidae.

The group was given family rank by Foerster (1856), who established the family Myinidae, based on the genus Myina Nees, a junior synonym of Aphelinus

Dalman. The family is also closely allied to the Signiphoridae (Woolley, 1988). Several schemes have been suggested for the subfamily and tribal classifications of the family. Early workers (Howard, 1907; Ashmead, 1904) divided the then subfamily Aphelininae (Encyrtidae) into two tribes - the Aphelinidini with 5-segmented tarsi and the Pteroptricini with 4-segmented tarsi. De Santis (1946) offered the first modern day classification recognizing three subfamilies: Aphelininae, Coccophaginae and Calesinae. Ferriere (1964) added a fourth subfamily, the Eriaporinae. Yasnosh's (1976) classification of the family into seven subfamilies was not accepted by other workers (DeBach and Rosen, 1976). Hayat (1985) proposed four subfamilies and eight tribes. Viggiani and Battaglia (1984) defined five aphelinid subfamilies based on male genitalia characters, placing the genus Eretmocerus as the sole member of the subfamily Eretmocerinae. They did not recognize the subfamily Eriaporinae and placed the genus Eriaphytis, traditionally placed in the Eriaporinae, in the subfamily Aphelininae. The first "modern" key to the world genera of Aphelinidae was published by De Santis (1946). Ferriere (1965) and Nikolskaja and Jasnosh (1966) published keys to the genera based on females only. Hayat (1983;1985) provided the most recent comprehensive keys to the aphelinid genera.

3.2. New World Studies in the Genus Encarsia

Major contributors to the knowledge of the North American and Caribbean Encarsia fauna include L. O. Howard (1894-1912), who described thirteen species:

United States (10), Mexico (1), and Puerto Rico (2); A. B. Gahan (1927-1931), 6 species: U.S.A. (3), Puerto Rico (2) and Cuba (1); and Dozier (1932-1937), 4 species: U.S.A. (1), Haiti (2) and Puerto Rico (1). Other early contributors include Tower (1913) and Cockerell (1911). Modern-day contributors include DeBach and Rose (1981); Viggiani (1989), who described one species from the U. S. and provided figures and additional notes on many of the previously described New World species; and Polaszek et al. (1992).

De Santis is the major contributor to the knowledge of the South American fauna of Encarsia. He described four species of Encarsia (two currently valid), redescribed in more detail several species, and has made major contributions to the overall study of the Aphelinidae and other chalcidoid families from the area. Several authors have described single species from South America (Blanchard, 1940; Hempel, 1904; Marelli, 1933; Mercet, 1927; Silvestri, 1936; Viggiani, 1987).

3.3. Generic Concepts

Encarsia Foerster 1878:65.

Type-species: Encarsia tricolor Foerster by original designation.

Synonyms

Aleurodiphus DeBach and Rose 1981:659. Type-species: Aleurodiphus americanus DeBach and Rose, by original designation. Synonymy by Hayat 1983:85.

Aspidiotiphagus Howard 1894a:229. Type-species: Coccophagus citrinus Craw, by original designation. Synonomy by Viggiani & Mazzone 1979:44.

Doloresia Mercet 1912:294. Type-species: Doloresia filicornis Mercet by original designation. Synonomy by Mercet 1930a:191.

Mimatomus Cockerell 1911:464. Type-species: Mimatomus peltatus Cockerell, by monotypy. Synonomy with Prospaltella by Girault 1917:114.

Paraspidotiphagus Alam 1956:359. Type-species: Aspidiotiphagus flavus Compere, by original designation (as subgenus of Aspidiotiphagus).

Prospalta Howard 1894b:6. Type species: Coccophagus aurantii Howard, designated by the ICZN under its Plenary Powers, Opinion 845 (preoccupied by Prospalta Walker, 1857, in Lepidoptera).

Prospaltella Ashmead 1904:126. Replacement name for Prospalta Howard nec Walker. Synonomy by Viggiani & Mazzone 1979:44.

Prospaltoides Brethes 1914:12. Type-species: Prospaltoides howardi Brethes by original designation, monotypic. Synonomy with Aspidiotiphagus by Brethes 1916:429. Ferriere (1965) considered type species a synonym of Encarsia citrina (Craw).

Trichaporus Foerster 1856:2. Nomen nudum, LaSalle & DeBach 1982:297.

The genus Encarsia is one of 16 genera included in the subfamily Coccophaginae, sensu De Santis (1948) and Hayat (1985), and has been placed in the tribe Pteroptricini (Hayat, 1989). Monophyly of the genus Encarsia is supported by the short axillae, by the pattern of mesoscutal setae (Polaszek and

Hayat, 1992) and by the spoon-shaped phalophase of the male genitalia (Viggiani and Mazzone, 1982). The genera Coccophagooides Girault, Coccophagus Howard, Dirphys Howard and Encarsiella Hayat are considered to be its closest relatives (Polaszek and Hayat, 1992).

Foerster (1878) erected the genus Encarsia with E. tricolor as its only included species. Walker described the genus Prospalta and designated murtfeldtae as its type species. Ashmead (1904) replaced the name Prospalta with Prospaltella as it was preoccupied by the genus Propalta Walker (Lepidoptera). Mimatomus Cockerell and Doloresia Mercet were synonomized with Prospaltella by Girault (1917) and Mercet (1930a) respectively. Viggiani and Mazzone (1979) synonomized Aspidiotiphagus Howard, Prospaltella and Trichoporus (Foerster) with Encarsia. Hayat (1983) synonomized Aleurodiphus DeBach & Rose with Encarsia. The synonymy of Aspidiotiphagus with Encarsia was not accepted by all workers (DeBach & Rose 1981), but Hayat (1989) agreed that the characters used to separate the genera were not considered of generic value and suggested that the differences only warrant the designation of a separate species group. The synonymy of Encarsiella Hayat with Encarsia proposed by Shafee and Rizvi (1984) was not accepted by Hayat (1989) because it was based only on the literature and not of study of relevant material. The generic name Trichaporus (Foerster) is considered a nomen nudum because Foerster who created the genus, failed to assign a species to it. Subsequently, Ashmead designated Trichoporus columbianus in 1900 as the type species for the genus Trichoporus. Both

Trichaporus Foerster and Trichoporus Ashmead are objective synonyms. LaSalle and DeBach (1982) stated that these genera are properly placed in Eulophidae, not in the Aphelinidae, where they are both senior objective synonyms of Galeopsomyia Girault (a eulophid) and sought suppression of the name by the International Commission of Zoological Nomenclature (ICZN).

Hayat (1989) provided a detailed description of the genus Encarsia and of the diagnostic characters that separate it from other closely related genera. Briefly, antennae 8-segmented, excluding the radicle and anellus, and occasionally 7-segmented in some males in which the F5 and F6 are partially or completely fused; tarsal formula 5-5-5 rarely 5-4-5; mesoscutum with 0-18 setae (usually 4-12) arranged in bilateral symmetry; scutellum with 2 pairs of setae (extranumeral setae rarely occur); hypopygium not prominent and rarely extending beyond the cercal plates; two setae on the submarginal vein (except in lounsburyi, which has one, and pulliclava, which has several); strong seta (mvb) at the juncture of the submarginal vein and marginal vein; forewing never with speculum; gaster with seven tergites; male genitalia with the phallophase several times longer than wide, with a truncate or rounded apex and without digit; aedeagus longer than the phallophase; body color variable with males generally darker than females. Encarsia may be distinguished from Coccophagus and Coccophagoides by having only two setae on the submarginal vein and scutellum whereas in the latter two genera, there are at least three setae on the submarginal vein and usually three (rarely two) setae on the scutellum (Figure 6.1i,k;6.3e,f;6.5b,c). Also, the marginal

vein is less than or equal to costal cell, the antennae are spindle-shaped with apex pointed; and the hypopygium is prominent, reaching at least to level of cercal plates in Coccophagooides.

Encarsia may be distinguished from Dirphys and Encarsiella, which have the axillae long, mesally separated by a distance of less than the length of an axilla. The mesoscutal setae are dense (more than 25) and scattered (Figure 6.4g,h). The scutellum width is less than 1.5 times its length, the submarginal vein has two prominent setae and usually with one to five setae at its base, and the club is often oblique and much wider than the funicle segments (Figure 6.1c,d). (Refer to pp. 231-232 of Hayat [1985] for a taxonomic key to separate these genera).

CHAPTER 4

MATERIALS AND METHODS

4.1. Natural Enemy Survey4.1.1. Collection

A statewide survey of the natural enemies of the SPWF was initiated in 1988 to gather information on the parasitoid complex of the SPWF in Florida and the humid neotropics, and to identify promising natural enemy species from the neotropics (and other areas of the world) for eventual introduction into Florida and the southern United States. The objectives of the survey were to:

- 1) identify the species of parasitoids commonly found parasitizing SPWF.
 - 2) measure the ratio between emergent SPWF and parasitoids as a comparative indicator of parasitism.
 - 3) identify important SPWF wild host plant reservoirs.
 - 4) identify changes in the parasitoid complex composition attributable to seasonal, geographic and host plant variation.
 - 5) determine if SPWF and its parasitoids can overwinter in northern Florida
- In addition, parasitoids were reared from several other whitefly species in order to determine the host range for each of the parasitoid species reared from SPWF.
(Bennett et al. 1990)

Samples of SPWF were collected from over 117 crop and weed species in 28 counties (Figure 4.1) in Florida by Dr. Fred D. Bennett, Dr. David Schuster, Emily Vasquez and other University of Florida cooperating scientists and field personnel. In addition, collections of parasitized SPWF were made in many Caribbean and Latin American countries (Figure 4.2), primarily by Dr. Bennett while traveling on other projects.

Host plant material was examined for the presence of whitefly pupae, after which the leaves containing higher numbers of whitefly pupae were preferentially selected and placed in 1/2-pint, pint or quart size paper cans (Gainesville Paper Co.) for parasitoid emergence. The inside lid of the paper can was covered with a paper tissue or fine netting before closing to prevent the parasitoids from escaping upon emergence. This method was preferred because it requires less handling time and increased the probability of parasitoid emergence by confining a larger number of parasitized hosts with less manipulation. However, erroneous host records may result when more than one host species are present in the sample. The plant material was examined carefully under the dissecting microscope for any other insects present, and were removed before placing the plant material into the container. To ensure accurate host records, each individual host should be isolated by removing a small leaf-disc bearing a single host with a hole punch and placing it into an individual vial. Whether the method used to collect and hold SPWF nymphs for parasitoid emergence equally affects the number of adult whiteflies and parasitoids or the species of parasitoid that emerge,

is not known. The emergence of parasitoid species, such as Eretmocerus that attack earlier nymphal stages and have a longer life cycle than Encarsia species, may be more affected as the host plant material held for parasitoid emergence, deteriorates. Data presented of the relative abundance of each parasitoid species in foreign countries are based on collections made on certain host plants at certain time of the year and at certain locations. They may not be representative of the true relative abundance of each species in the area.

Each collection was given an accession number and the following collection data recorded: 1) locality - country, state or department, city or town, property; 2) date of collection; 3) collector; 4) host insect; 5) host plant; 6) infestation level - very high, high, medium, low, and very low; 7) number of leaves per sample; and 8) field notes. Rating the infestation levels was done subjectively, and varied with the size of the leaf.

The contents of each container were examined three to four weeks after collection. The dry, dead wasps were sorted to species, counted, sexed (for some localities), then removed with a fine brush or a minutén pin glued to the end of a 2-mm diameter dowel rod. Microscope slide preparations were made of the host and parasitoids, when necessary to identify or confirm the identification of the species. Specimens representing new host or distribution records or other special cases were processed similarly. Additional parasitoid specimens were stored dry, in small glass vials or gelatin capsules with some loose cotton to prevent their movement and breakage. Records were kept of the number of adult whiteflies, and

of females and males of each parasitoid species that emerged. Collections of other whitefly species were processed similarly, with the exception that only the identity of each parasitoid was recorded. Slide labels were printed on dry gum paper with the laser printer using Word Perfect 5.1 software. Collection data and parasitoid identifications were input into PARADOX 3.5 database software for storage, retrieval and analyses of data.

The number of leaves collected per sample sometimes varied for different plant species. For example, 30 or more leaves per sample were collected of *Chamaesyce hyssopifolia*, which has small leaves, while only 3 to 4 leaves per sample were collected of *Brassica oleracea*, a large leaf host. Collections were made periodically in specific areas from certain plants while other collections were made opportunistically whenever an infestation of SPWF was encountered. Collections were not made at random since the primary focus of the survey was to determine the identity of the parasitoid species that attack the SPWF.

Leaves containing higher numbers of late-instar whitefly pupae were preferentially selected to be held for parasitoid emergence, in order to maximize the number of adult parasitoids that emerged. Most collections were made in areas that were not treated with pesticides, such as roadsides, organic gardens and field plots that were not treated. Nevertheless, there were several collections made in areas that had been sprayed with pesticides.

Percent parasitism was calculated by dividing the number of parasitoids by the sum of the number of SPWF and parasitoid adults that emerged. McAuslane

(personal communication) found that direct observation of parasitized SPWF late-instar pupae on peanut leaves, determined by the displacement of the mycetomes in the nymphal body, overestimated the percent parasitization or emergence data underestimated the percent parasitization. The data, although highly variable, showed that the number of adult whiteflies that emerged was about 50% that of the number of 4th instar nymphs and red-eyed nymphs (pharate adults) present on the leaf. Percent parasitization was about 16% of the number of observed parasitized SPWF pupae.

4.1.2. Mounting and Preservation

Whitefly late instar nymphs were cleared in 10% KOH, stained in "Wilkey's double-stain", and passed through baths of 70 and 95% alcohol, a 1:1 mixture of 95% and clove oil, and pure clove oil before mounting them in Canadian balsam. They were then sent to Dr. Avas Hamon, Division of Plant Industry, Gainesville, Florida for identification. Most of the slide-mounted parasitoid specimens were processed by clearing them in lactophenol for three to four days. They were then bathed in Nesbitt's formula to remove excess lactophenol, and mounted, with wings and appendages extended, on microscope slides in Hoyer's medium (see Krantz (1978) for formulae for Hoyer's and Nesbitt's solutions). Slides with mounted specimens were placed on a hot plate at 50°C for about two weeks or until dry before sealing the edge of the coverslip with a ring of GLYPT solution. Hoyer's medium was preferred because it requires less manipulation of the

specimen and processing time, better preserves the color of the specimen, provides a better resolution and reveals more details than using balsam. Also, antennae and other body structures may collapse while processing specimens for balsam mounts unless special care is taken in processing the specimen. However, since Hoyer's is not a permanent medium, it is uncertain how long the mount will last before becoming cloudy or crystallized as the Hoyer's medium deteriorates. Therefore, it is recommended that specimens be mounted in balsam to ensure their longevity, especially those representing new species or other specimens of special interest. Noyes (1982) gives a thorough procedure for mounting specimens in balsam. Specimens are dissected and the head, wings, antennae and body are placed under four separate 3-mm microcoverslips. More accurate measurements of the body parts are achieved and better photographs are taken, because each dissected body part is flat and on the same focal plane.

Storage in alcohol, for conventional taxonomy, was avoided. Specimens stored in alcohol when placed directly in lactophenol do not clear sufficiently and make unsatisfactory slide mounts. If specimens have been preserved in alcohol, they should first be dried before beginning the slide mounting process. Specimens were not pointed or mounted on cards because of their small size. Also, they tend to shrivel and many of the characters used for identification cannot be observed. However, for DNA analyses or Scanning Electron Microscopy, specimens should be preserved frozen at a temperature of no higher than minus 20°C, (preferably minus 80°C). Specimens can be preserved in 80% ethyl alcohol for Scanning

Electron Microscopy. Alcohol storage of specimens is not highly recommended for DNA analyses; when used, specimens should only be stored for short periods of time.

4.2. Systematic Studies

Several thousand slide-mounted specimens of parasitoids reared from the SPWF and at least forty other whitefly species were examined. The majority of the specimens were collected in Florida, but specimens from California, Georgia, Louisiana, Maryland, New York, South Carolina, Tennessee, Texas, Mexico, Guatemala, Honduras, El Salvador, Costa Rica, Puerto Rico, Jamaica, Guadeloupe, Grenada, Venezuela, Colombia, Bolivia and Brazil, were also examined. Type specimens and additional specimens of several described species were borrowed from the U. S. National Museum and El Museo Nacional de La Plata, Argentina, for examination. Extralimital specimens reared from the SPWF and other hosts collected in India, Thailand, China, Hong Kong, Egypt and Sudan were also examined.

4.3. Morphology and Explanation of Terms and Measurements

Rosen and DeBach's (1976) have discussed in detail the morphology of the genus *Aphytis*. With few exceptions, most of their discussion is relevant to the genus *Encarsia*. Body measurements were taken as prescribed by Hayat (1989) from slide-mounted specimens. The body is divided into three well-defined regions (Figure 4.3): 1) the head, including the eyes, mouthparts and antennae; 2) the mesosoma, comprising the three thoracic segments (pronotum, mesonotum and

metanotum), legs and wings. The mesonotum is divided into the mesoscutum (or midlobe), the axillae and the side lobes (or parapsides). The metanotum consists of the scutellum and metanotal ridge. Between the metanotum and the gaster is the propodeum, which is actually the first abdominal segment; 3) the gaster which is separated from the propodeum by the petiole, is composed of the seven subsequent abdominal segments designated as tergites I-VII. Tergum VII is sometimes referred to as the syntergum.

The body length was measured from the anterior margin of the head to the most posterior point of the gaster. The head was measured across its maximum width. Setae found on the head are prefixed by an "h". Setae found on the postoccipital bars (hb) are designated as hb1 (central pair), hb2, hb3, etc. (moving laterally toward the compound eyes). Posterior to the postoccipital bars is a row of prominent setae designated as "hp" setae (Figure 4.3). The mandibles are usually tridentate and the maxillary palp 1- (rarely 2) segmented. The number of setae between the antennal bases and Table occipital triangle, the number of labial and maxillary palp segments and sculpturing of the occiput and stemmaticum were also noted.

When counting the number of antennal segments, the radicle and anellus are excluded. Therefore, for female Encarsia species the antennae is 8-segmented, consisting of the scape, pedicel and flagellum. The flagellum is 5 or 6-segmented consisting of 2 to 4 funicle segments and 2 to 4 club (or clava) segments. For simplicity, the funicle and club segments will be labeled consecutively as F1, F2, F3, F4, F5 and F6 (Figure 4.4 b,c). The club may be 3-segmented (formed by F4, F5, F6), 2-segmented (F5, F6), or not clearly

Table 4.1. Morphological and Setal Abbreviations Used.

Ax	Axilla
as	axilla setae
dl	disk length
dw	disk width
F1	Funicle (1st segment)
F2-6	Funicle (segments 2-6)
Gs	Gaster
gc5	gastral central setae (tergite V)
gc6	gastral central setae (tergite VI)
gc7	gastral central setae (tergite VII)
gl1	gastral lateral setae (tergites I)
gl2-7	gastral lateral setae (tergites II-VII)
gs	genital setae (ovipositor plate)
hb	occipital bar
hb1	occipital bar setae (central pair)
hb2	occipital bar setae (2nd lateral pair)
ho	occipital triangle setae
hp	postoccipital bar setae
ISD	intersensillar distance
MC	Mesoscutal posterior central setae (primary)
mc1	mesoscutal setae (1st central pair (=1st longitudinal row)
mc1R	mesoscutal seta (1st central seta, right side, unpaired)
mc1L	mesoscutal seta (1st central seta, left side, unpaired)
mc2-4	mesoscutal setae (2nd-4th pair of central setae)
md1	mesoscutal setae (1st pair in 2nd longitudinal row)
md2-4	mesoscutal setae (2nd-4th pairs in 2nd longitudinal row)
me1-4	mesoscutal setae (3rd longitudinal row)
mf1-4	mesoscutal setae (4th longitudinal row)
ML	Mesoscutal anterior lateral setae (primary)
Ms	Mesonotum
mf	marginal fringe
mv	marginal vein
mvb	marginal vein basal seta
oc	occiput
P	Pedicel
pob	postoccipital bars
PSD	Placoid sensillum diameter
R	Radicle
S	Scape
Sc	Scutellum
Sc1	Scutellar setae (anterior pair)
Sc2	Scutellar setae (distal pair)
sm	stemmaticum
smv	submarginal vein
smv1	submarginal vein setae (mesial pair)
smv2	submarginal vein setae (apical pair)
sv	stigmal vein
VII	2nd valvular segment
VIII	3rd valvular segment
vs	ventral setae

differentiated. Males of some *Encarsia* species have 7-segmented antennae in which the F5 and F6 segments are fused together. Funicle segments may bear several or no linear sensilla and/or short, club-like sensilla. The number of linear sensilla on each funicle segment is given in sequence for F1-F6, respectively. For example, (0,0,2,2,2,3) indicates that there are no linear sensilla on F1 and F2, 2 sensilla on F3, F4 and F5, and 3 on F6. At the apical end of F6 there are usually 2 to 3 finger-like sensilla. The male F2 antennal segment may exhibit various kinds of specialized sensory processes. For example, the F2 antennal segment of *E. nigricephala* males has round, pit-like sensorial processes and the males of *E. cibensis* have short arrow-shape processes. The length of the pedicel, by convention, is measured along the ventral side, since in side view it rarely forms a perfect isosceles triangle, making its dorsal length usually greater than its ventral length (Figure 4.4d). Unlike Hayat, I prefer to compare the relative lengths of antennal segments to the F1 segment because of difficulties in accurately measuring the pedicel.

The mesoscutum was measured from the center of the anterior margin to the center of the posterior margin; the width was measured at the level of, but excluding, the tegulae. The number of setae, setal type and sculpturing of the mesoscutum are useful characters for distinguishing species. Setal number and position on the mesoscutum are often designated in the literature in the form of setal formula. Some ambiguity exists because authors that have used this method give no mention of how they derived the formula and the same methodology has

not been used consistently throughout the literature. An example of a formula commonly used would be (4+2+2+2), which indicates that there are 4 setae (including the large pairs of setae in the upper lateral corners of the mesoscutum) across the anterior margin of the mesoscutum, followed by 3 pairs of central setae.

Alternately, the following method is proposed to name and better pinpoint the position of a particular seta. Setae are prefixed by the first letter of the body part on which they are found. Primary setae are designated by capital letters and secondary setae by small letters. Setae found on the head, mesoscutum, scutellum, axilla and gaster begin with "h", "m", "s", "a" and "g", respectively (refer to figure 4.3). With few exceptions, the mesoscutum of Encarsia species possesses at least the primary setae ML and MC located in the anterior corner close to the tegulae and the posterior margin, respectively. The secondary mesoscutal setae are designated as follows: the central setae are designated as "mc" setae, followed by longitudinal rows of "md", "me" (rarely "mf") setae moving toward the lateral margins. The setae are numbered 1, 2, 3 or 4, based on their lateral position. The setae found along the anterior margin or the anterior quarter of the mesoscutum are designated as "1" setae. The setae found between the anterior quarter and the middle, between the midline and the posterior three-quarters, and the posterior three-quarters and the MC setae of the mesoscutum are designated as 2, 3 and 4, respectively. The name and position of a particular seta can be designated by using a combination of the longitudinal and lateral positions. For example, mc1 indicates the pair of setae in the central position along

the anterior margin of the mesoscutum. The remainder of the secondary setae are designated following the same scheme for each of the longitudinal rows of setae (md, me and mf). Unpaired setae can be referred to by adding an "R" (right) or an "L" (left) to the designated seta. For example mc3R, would indicate an unpaired central seta on the right side between the midline and posterior three-quarters of the mesoscutum. For the setal formula, each seta is prefixed in the setal formula by the number of setae of that type. The formula (2ML;2mc1,2,4+2MC;2md1,2) indicates one pair of ML setae, three pairs of mc setae plus the MC setae, followed by 2 pairs of setae adjacent to the central setae.

The scutellum was measured at its maximum length from the center of the anterior to the center of the posterior margin, and its maximum width across the transverse midline. The ratio of the intersensillar distance to the placoid sensillum diameter (ISD:PSD) was determined by dividing the distance between the bases of the placoid sensillae (ISD) by the width (diameter) of one sensillum (PSD). The scutellar setae are designated as Sc1 and Sc2, for the anterior pair and posterior pair of setae, respectively.

Each axilla always bears one seta in Encarsia, designated as "as1," which is usually located toward the apex of the axilla but may be found centrally in some species. The axillae were measured from their anterior to their base and the position of the axilla seta from its base to the base of the axilla.

All of the legs are 10-segmented (rarely 9), consisting of the coxa, trochantellus, trochanter, femur, tibia, and 5 (rarely 4) tarsal segments. The stigil,

a comb-like structure used for grooming, is present on the foreleg. The tibia of leg II, referred to as the midtibia or tibia II, and the hindleg bear a saltatorial spur, which is usually much larger in the former. The coxae of the hindlegs are more robust than those of the forelegs or midlegs. The tarsi in some species have the two apical tarsal segments of the midleg fused together (i.e. 4-segmented). Tibia II was measured from the apex of the femur to the apex of the basitarsus. Basitarsus II was measured along its longest axis. The endophragma was measured from the anterior edge of the scutellum to its most posterior point.

The gaster comprises segments II-VIII of the abdomen (excluding the propodeum, which is the first abdominal segment). The segments of the gaster are designated, starting with the first segment posterior to the petiole, as tergites I-VII. The cercal plates located at the base of tergum VI are useful for orientation. The gaster may bear one or several lateral setae designated as "gl" setae followed by 1-7, depending on the tergum on which they are found. Central setae are usually found on tergites V, VI and VII and are designated as gc 1-7, depending upon which tergum they are located on. One to several rows of ventral setae (vs) are located between coxa III and the anterior margin of the ovipositor.

The ovipositor may be exserted or not. The ovipositor shaft is composed of three parts: a pair of serrated stylets (the first valvulae); an unpaired smooth component (the second valvulae); and the sheaths, or third valvulae (also called gonostyli) (Figure 4.4e). The ovipositor field or plate is a sunken area on the venter, demarcated by a ridge running between the first valvulae and the posterior

margin of the gaster; genital setae (gs) are usually found in transverse rows and are designated by a formula that counts the number of pairs of setae in each row beginning with the most anterior pair of setae. Setae located on the third valvular segment are designated as "vc" and "vd" for the central and distal setae, respectively. The ovipositor was measured from its anterior margin (the anterior edge of the valvular I) to its tip. Valvular II was measured from the same anterior edge as the ovipositor to the apex of valvular III. The length of valvular III was measured from its juncture with valvular II to the most posterior point, and the maximum width was measured across the anterior margin including both papillae and the ovipositor (Figure 4.4e).

The venation of the forewing is reduced, consisting of a submarginal vein (smv), marginal vein (mv), stigmal vein (sv), parastigmal vein (pv) (Figure 4.4a). The parastigmal vein is greatly reduced in Encarsia and bears 1 setae (pv). Just posterior to the base of the parastigmal vein and along the posterior margin of the submarginal vein, are the basal setae (bs). The submarginal vein is usually shorter than the marginal vein and almost always bears only two setae, designated as smv1 and smv2. The marginal vein is equal to or longer than the submarginal vein. The setae along the anterior border of the marginal vein were designated with the most mesially-directed seta designated as mv1 followed by mv2, mv3, etc. toward the apex of the forewing.

The length of the forewing was measured from the wing base to the furthest distal point of its apex; the submarginal vein from the wing base to the pv1 seta;

the marginal vein from the p_{v1} seta to its apex. The length of the forewing disk, or discal cell, (dl) was measured by first determining the intercept of the bisect that divides the forewing into anterior and posterior halves, with a line drawn from the stigmal vein, running perpendicular to the bisect line; then measuring the line drawn from the intercept to the apex of the forewing (Figure 4.4a). The disk width (dw) was measured at the maximum width of the disk.

Figures of new and described species were not drawn to scale, so their dimensions cannot be compared with those of other drawings. Figures 5.12b,c; 5.15c and 5.24b,d were drawn free-hand by Kurt Ahlmark, Division of Plant Industry, Gainesville, Florida. Other figures were drawn by the author with the aid of a drawing tube or modified from those found in the literature. Acronyms used in the text for holotype depositories following those given by Heppner and Lamas (1982) are given below.

Table 4.2. Acronyms Used for Holotype Depositories.

AMEI	American Entomological Institute, Gainesville, Florida, USA.
BPBM	Bernice P. Bishop Museum, Honolulu, Hawaii, USA.
FSCA	Florida State Collection of Arthropods, Gainesville, Florida, USA.
IEUN	Istituto di Entomologia Agraria, Universita degli Studi di Napoli, Portici, Italy.
MCNG	Museo Civico di Storia Naturale, Genoa, Italy.
MNN	Museo Nacional de Ciencias Naturales, Madrid, Spain.
NHM	Natural History Museum (British Museum), London, England.
UCR	Division of Biological Control, University of California, Riverside, California, USA.
UNLP	Universidad Nacional de La Plata, Argentina.
UNP	Universita degli Studi di Napoli, Portici, Italy.
USNM	United States National Museum of Natural History, Washington, DC.

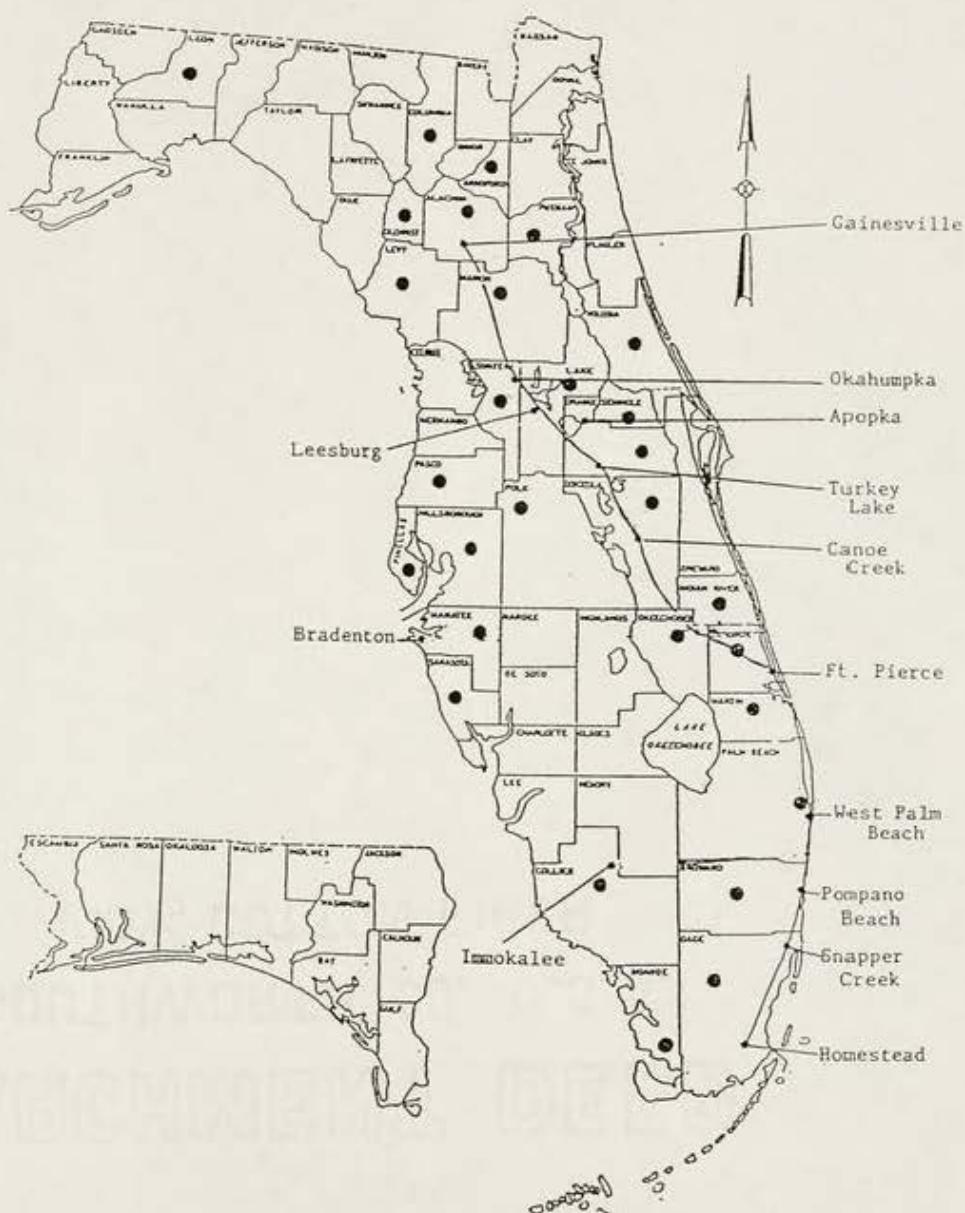


Figure 4.1. Florida Counties and Major Sites Sampled for SPWF Parasitoids.

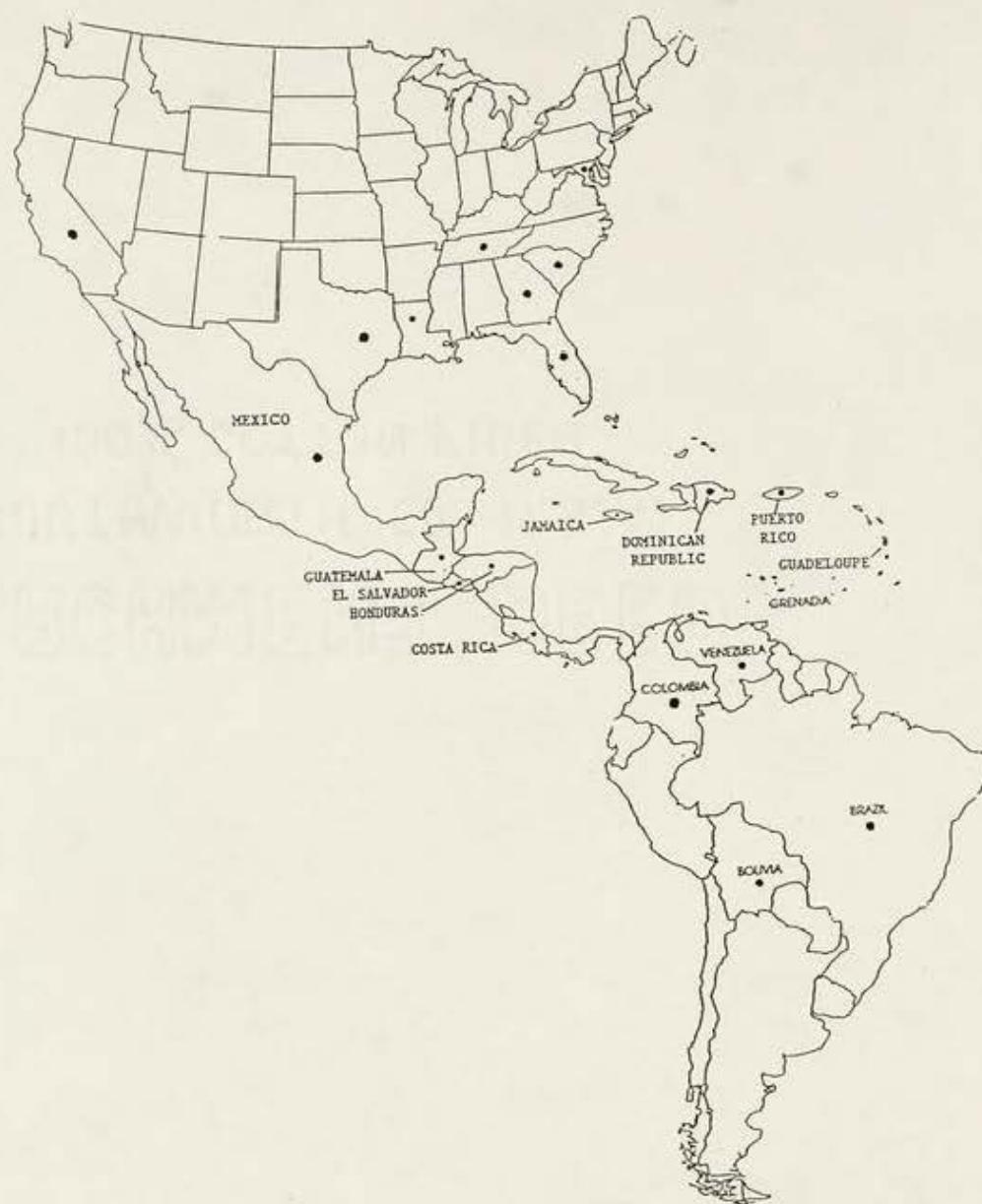


Figure 4.2. USA, Caribbean and Latin American Countries Sampled for SPWF parasitoids.

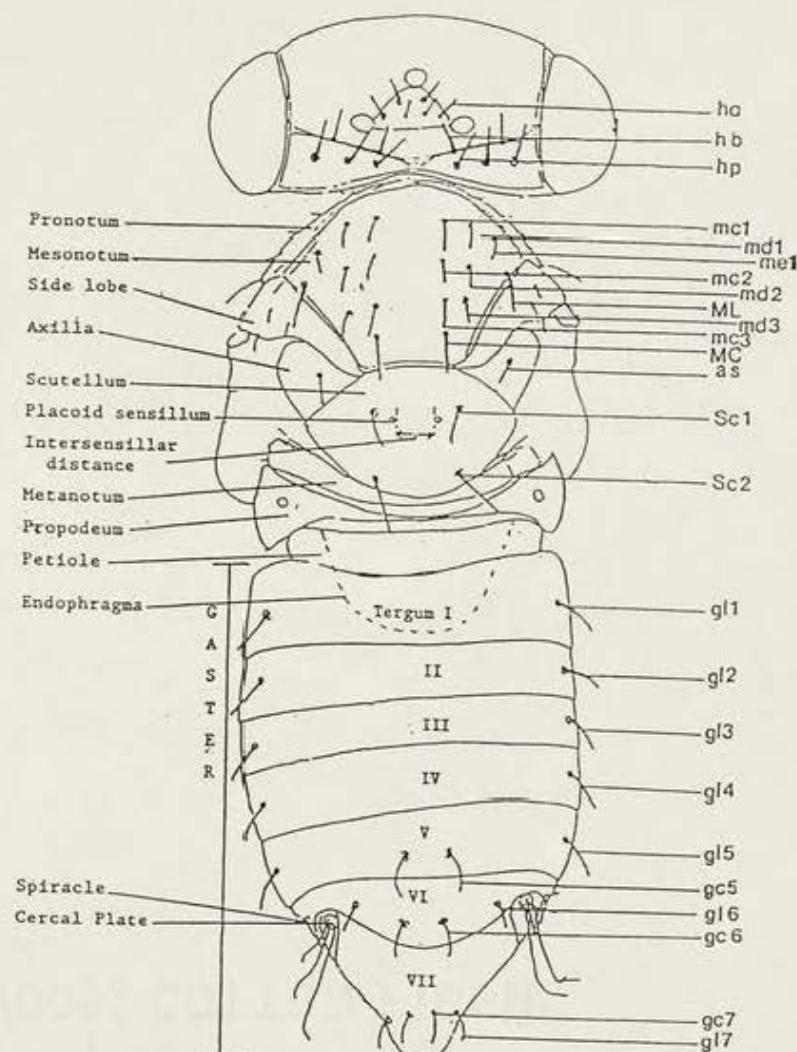


Figure 4.3. Female Encarsia morphology and setal nomenclature.

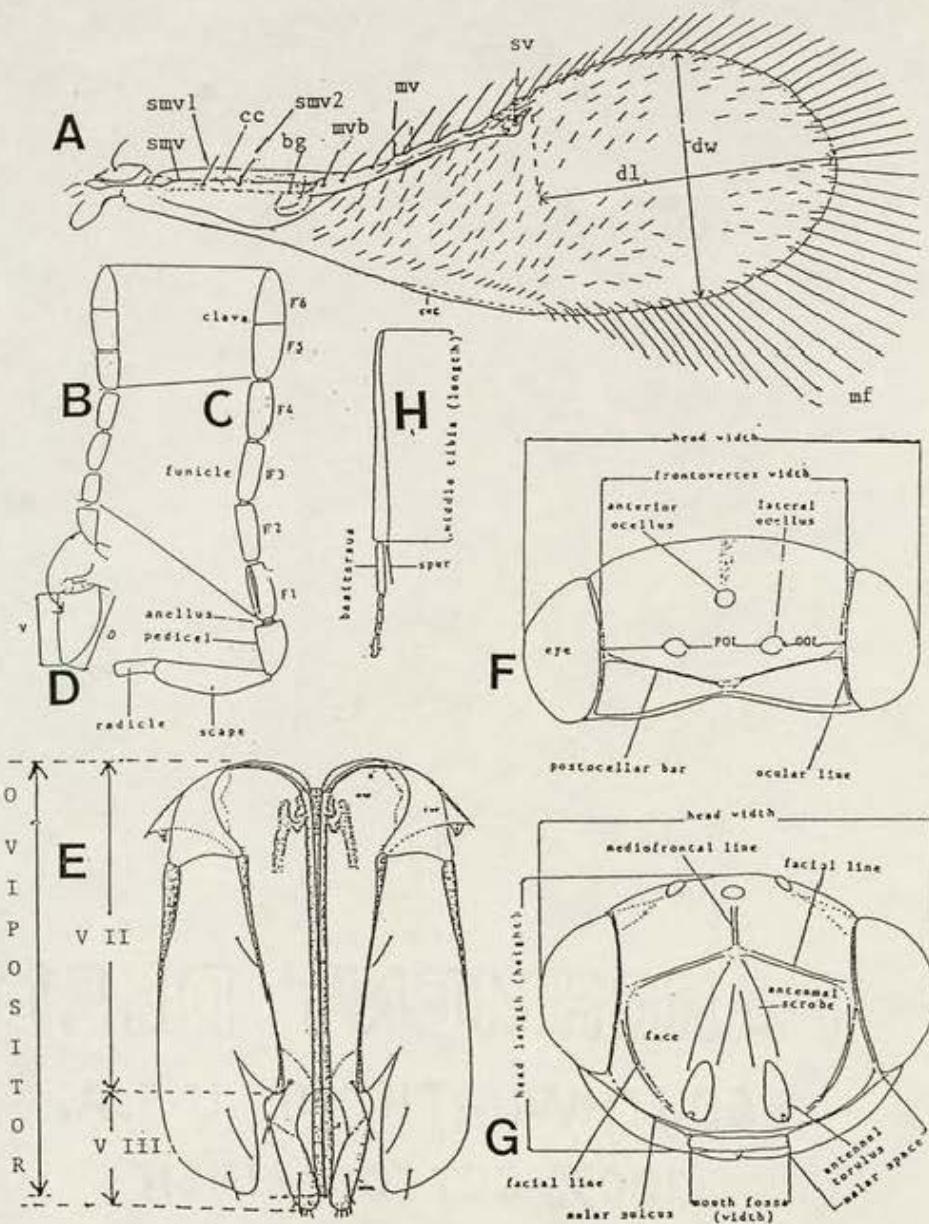


Figure 4.4. Female Encarsia A) forewing B) antenna with 3-segmented club
 C) antenna with 2-segmented club D) pedicel E) ovipositor
 F) superior view of head G) frontal view of head.

CHAPTER 5

KEYS TO GENERA, SPECIES GROUPS AND SPECIES

5.1. Introduction

The following taxonomic keys are based on characters found in the adult female, unless otherwise indicated. Two keys are presented. The first is a key to the hymenopterous parasitoid genera that attack whiteflies, followed by a brief discussion of each genus. The second key is to the *Encarsia* species groups and a key to the native and exotic *Encarsia* species parasitizing aleyrodids in the New World. *Encarsia* species that parasitize non-aleyrodid hosts are keyed only to the level of the species group. It is necessary to mount the specimens on microscope slides and examine them under a compound microscope with at least 100x power to observe many of the characters used in the key.

5.2. Key to the Parasitoid Genera that Parasitize Aleyrodids

1. Antennae 9 to 11-segmented. Marginal vein lacking or very short.(Figures 5.1:a,b;5.2:a,b).....2
- 1b. Antennae 8-segmented or less. Marginal vein long and well developed....3

- 2(1) Antennae 10-segmented, including fused 3-segmented club (Figure 5.1:a).
 Marginal and stigmal veins lacking (Figure 5.2:a). Pronotum reaching tegula (Figure 5.5:a). Midtibial spur short and slender. Male club segments not fused. Body dark, robust and heavily sclerotized [Proctotrupoidea: Platygasteridae].....Amitus
- 2b. Female antennae 11-segmented, male antennae 9-segmented (Figure 5.1:b). Marginal vein very short, about as long as stigmal vein (Figure 5.2:b). Axillae with their apices meeting in the center of the body (Figure 5.4:b). Pronotum separated from tegula. Midtibial spur large and thick. Body less robust and weakly sclerotized [Encyrtidae].
Metaphycus
- 3(1b). Antennae 3 to 6-segmented, apical segment greatly elongate, usually more than 4 times as long as the penultimate segment (Figure 5.1:f,g,j,l,m).....4
- 3b. Antennae 7 to 8-segmented, apical segment less than two times as long as penultimate segment (Figure 5.1:c,d,e,h,k).....6
- 4(3). Tarsal formula 5-5-5; forewing disk bare or with one seta (Figure 5.2:d), marginal fringe longer than maximum width of disk. Antennae with F1, F2, and F3 ring-like (Figure 5.1:j).[Signiphoridae].
Signiphora
- 4b. Tarsal formula 4-4-4; forewing disk setose, at least with several rows of setae.....5

- 5(4b). Forewing very narrow and with 3-4 rows of discal setae, disk length and marginal fringe about 2 times as long as maximum disk width (Figure 5.2:e). Antennae 6-segmented, F1 and F2 ring-like. Male antennae 4-segmented. (Figure 5.1:m,l) [Aphelinidae].....Cales
- 5b. Forewing broad and uniformly setose, disk about as long as wide, marginal fringe less than 0.5 times maximum disk width (Figure 5.2:c). Female antennae with F1 and F2 short and F3 elongate. Male antennae 3-segmented (Figure 5.1:f,g). [Aphelinidae].....Eretmocerus
- 6(3b). Tarsal formula 4-4-4. Antennae 7-segmented, F1 ring-like, very short, more than twice as wide as long (Figure 5.1:h). Stigmal vein very elongate (Figure 5.3:c). Known species are dark colored (Figure 5.4:c). [Eulophidae]
.....Euderomphale
- 6b. Tarsal formula 5-5-5 (rarely 5-4-5). Antennae 7 or 8-segmented, F1 not ring-like, usually longer than wide. Stigmal vein not very elongate [Aphelinidae].....6
- 7(6b). Antenna 7-segmented, often with dark and pale funicle segments, club one segmented (Figure 5.1:e). Forewing hyaline with dark markings and small area of long coarse setae under the stigmal vein (Figure 5.2:f). Male antennae uniformly colored.....Azotus

- 7b. Antennae 8-segmented (7-or 8-segmented in male) usually uniform in color. Forewing setae uniform (lacking small area of coarse setae under the stigmal vein).....8

8(7b). Axillae usually relatively short, mesally separated by a distance greater than the maximum length of one axilla. Mesoscutum with fewer than 25 setae (usually less than 15) arranged in bilateral symmetry (Figure 5.5:e).

F5 straight, not oblique (Figure 4.4:c). Tarsal formula 5-5-5 rarely 5-4-5. Two submarginal vein setae, rarely 1 or more than 2.....Encarsia

- 8b. Axillae long, mesally separated by a distance less than maximum length of one axilla. Mesoscutum densely setose with more than 25 setae not arranged in bilateral symmetry. F5 segment oblique or straight (Figure 5.1:c,d). Tarsal formula 5-5-5. Submarginal vein with 2-3 large setae plus a variable number of smaller setae at the distal end (Figure 5.3:a,b)....9

- 9(8). Mesoscutum sculpture aciculate (Figure 5.4:g). Intersensillar distance: placoid diameter ratio less than one. Side lobes divided.....Dirphys

- 9b. Mesoscutum sculpture imbricate/reticulate, intersensillar distance: placoid diameter ratio greater than 2. Side lobes not divided (Figure 5.4:h)

.....Encarsiella

5.3. Biological Characteristics of the Genera

5.3.1. Family Platygasteridae (Protrupoidea)

Genus Amitus Haldeman 1887

The genus Amitus is cosmopolitan in distribution. There are 11 described species. However three new species have been discovered during the course of the Florida survey of Bemisia parasitoids. Females of the new species reared from Bemisia tabaci in Puerto Rico are parthenogenetic, solitary parasitoids (F. D. Bennett, personal communication); males occur but are extremely rare. All species are known only from aleyrodid hosts. According to Flanders (1969), females of A. hesperidum develop gregariously while males develop as solitary parasitoids. This parasitoid was instrumental in bringing the citrus blackfly, Aleurocanthus woglumi, under control in many areas. Refer to Fouts (1924), MacGowen and Nebeker (1978) and Viggiani and Mazzone (1982) for descriptions of species.

5.3.2. Eulophidae (Chalcidoidea)

Genus Euderomphale Girault 1916

The genus Euderomphale contains 12 species. Euderomphale species have been reported primarily from whiteflies of the genus Aleyrodes. However, Viggiani (1977) described Euderomphale bermisiae from Bemisia citricola. J. LaSalle and M. Schauff are currently preparing a manuscript on the eulophid genera parasitic on aleyrodids. They treat six genera, four of them newly erected (M. Schauff, personal communication).

5.3.3. Encyrtidae (Chalcidoidea)

Genus Metaphycus Mercet 1925

The new Metaphycus species reared from Bemisia tabaci by F. D. Bennett from Venezuela is the only bonafide whitefly host record for this large genus. Most species of Metaphycus are parasitoids of soft and armoured scale insects (Noyes 1984). Dr. John Noyes of the Natural History Museum (NHM) confirmed the record by identifying the pharate (ready to emerge) Metaphycus adults still inside the late instar Bemisia tabaci pupae as well as individuals that later emerged from the host material.

5.3.4. Signiphoridae (Chalcidoidea)

Genus Signiphora Ashmead 1880

Woolley (1988) in his review of the phylogeny and classification of the family Signiphoridae, included 36 described species plus several undescribed species in the genus Signiphora. Most of the described species are hyperparasites but a few are primary parasitoids of aleyrodids and diaspine scale insects. Signiphora aleyrodis (Girault) was reared several times from collections of Bemisia tabaci and other whiteflies in the survey, but is probably a hyperparasite of Encarsia or Eretmocerus larvae developing in the same host.

5.3.5. Aphelinidae (Chalcidoidea)

5.3.5.1. Genus Azotus Howard 1898

The genus Azotus is cosmopolitan in distribution and contains around 26

described species world-wide (Hayat 1983). Most species develop as hyperparasites, but occasionally they may develop as primary parasitoids. (Viggiani 1984). Azotus species were not reared from whitefly hosts collected in this survey, but occasionally were reared from samples containing diaspine scales.

5.3.5.2. Genus Cales Howard 1907

The genus Cales contains 3 species (Viggiani & Carver, 1988), C. noacki has been the only species reported from the New World; it is a primary parasitoid of the woolly whitefly, Aleurothrixus floccosus (Maskell) and Aleurotuba jelineki (Fraunf.).

5.3.5.3. Genus Dirphys Howard 1914

The genus Dirphys contains 4 species all are gregarious, primary parasitoids of whitefly species of the subfamily Aleurodicinae from the neotropics. Polaszek and Hayat (1992) in their revision of the genus, described two new species and provided a cladistical analysis of Dirphys and Encarsiella.

5.3.5.4. Genus Encarsiella Hayat 1983

Six species have been assigned to the genus Encarsiella (Polaszek and Hayat (1992), three of Neotropical and three of Oriental distribution. All but Encarsiella boswelli (Girault) which parasitizes eggs of Heteroptera, are recorded as parasitoids of the whitefly subfamily Aleurodicinae. All species are believed to develop as solitary parasitoids.

5.3.5.5. Genus Eretmocerus Haldeman 1850

The genus Eretmocerus contains about 32 species worldwide. Both males and females are solitary, endoparasitic, primary parasitoids of aleyrodids. Most species are arrhenotokous but thelytokous species have been recorded (Gerling 1966). Unlike Encarsia species, eggs are deposited underneath the aleyrodid nymph and no meconium is cast at the end of larval development. Eretmocerus species often constitute a large percentage of the parasitoid complex of an area. Eretmocerus mundus Mercet was introduced into Florida from Israel and Sudan for the biological control of Bemisia tabaci. Like Encarsia, species identification is complicated by limited knowledge of genus, especially of the New World fauna. Eretmocerus is currently being revised by Michael Rose of Texas A & M University. (See Compere (1936) and Hayat (1972) for species descriptions and taxonomic keys).

5.4. Key to Encarsia Species Groups of the World and Encarsia

Species that Parasitize Aleyrodids in the New World.

1. Tarsal formula 5-4-5 (Figure 5.7:a;5.8:h,k).....2
- 1b. Tarsal formula 5-5-5.(Figure 5.13:c,f,i).....3

- 2(1). Forewing with a large, round asetose (bare) area under stigmal vein (Figure 5.6:a,b,c). Mesoscutum usually with 2 to 3 pairs of setae. Male F5 and F6 of segments fused (Figure 5.7: c,f).(Cubensis Group)..15

- 2b. Forewing uniformly setose (Figure 5.8:a). Mesoscutum usually with more than 4 pairs of setae. Club usually 2-segmented. F5 and F6 segments fused or not. (Formosa Group).....17
- 3(1b). Forewing narrow, disk more than 1.5 times as long as wide. Marginal fringe long, at least 0.6 as long as maximum disk width (Figure 5.11:e;5.25:b,e). Mesoscutum with 0 to 4 pairs of setae (usually 2).....4
- 3b. Forewing moderate to broad, area under stigmal vein setose, marginal fringe variable but usually less than maximum width of disk (Figure 5.17b). Number mesoscutal variable, but usually more than 4 pairs.....6
- 4(3) Forewing with large, round asetose area under the stigmal vein. Petiole striated or not (Figure 5.11:e). Parasitoids of aleyrodids and diaspine scales.....5
- 4b. Forewing uniformly setose. Petiole rarely striated (Figure 5.26:h,i). Parasitoids of diaspine scales.....(Inquirenda Group)
- 5(4). Petiole with striate lines. Forewing often sharply inflexed (angled) posteriorly. Valvular III gonostyli short and thick, diaspine scales parasitoids (Figure 5.25:a,b,c).....(Citrina Group)

- 5b. Petiole smooth. Forewing not sharply inflexed. Valvular III gonostyli long and narrow (Figure 5.11). Parasitoids of aleyrodids....(Parvella Group).24
- 6(3b). Scutellum with intersensillar distance less than diameter of one sensillum (Figure 5.13). F1 usually cylindrical at least 1.5 times as long as wide and 0.75 as long as F2.....(Strenua Group).7
- 6b. Scutellum with intersensillar distance greater than the width of one sensillum. F1 length variable in length.....9
- 7(6). Club 3-segmented. Gaster orange or yellow (dark in bella). Forewing hyaline (Figure 5.13).....8
- 7b. Club 2-segmented, gaster usually dark brown or black. Forewing infuscate (Figure 5.16).....(Quercicola Subgroup).31
- 8(7). Body yellow to orange (some tergites may have dark transverse bands). Placoid sensillae kidney shaped. Ovipositor often long and/or extruded. Parasitoids of aleyrodids (Figure 5.13).....(Strenua Subgroup).27
- 8b. Body dark brown. Placoid sensillae round. Ovipositor moderate in length. Parasitoids of diaspine scales (Figure 5.26:a,b,c,d).....(Bella Subgroup)
- 9(6b) Pedicel distinctly longer than F1 (Figure 5.18:a,i).....10
- 9b. Pedicel subequal in length to, or shorter than F1 (Figure 5.21:c).....13

- 10(9). Ovipositor short to moderate (less than 0.8 times as long as midtibia) and valvular III short to moderate. Conical setae absent on basitarsus II (Figure 5.23:c).....11
- 10b. Ovipositor long (equal to or longer than midtibia) and valvular III long. Conical setae present on basitarsi of many species (Figure 5.18:g,k).....(Opulenta Group).34
- 11(10). Valvular III dark brown, in sharp contrast to pale ovipositor plate (Figure F1 quadrate, shorter than F2. Marginal fringe about 0.33 times as long as maximum width of disk. Male with F1-3 laterally expanded, and F5 and F6 fused (Figure 5.23:a-g).....(Lutea Group)
Only one species reported in the New World.....lutea (Masi)
- 11b. Valvular III pale. F1 cylindrical subequal to F2. Length of marginal fringe variable. Male F1-3 not laterally expanded.....12
- 12(11b). Ovipositor plate quadrate (Figure 5.25:f), mostly diaspine scale parasitoids.....(Aurantii Group)
One species parasitizing New World aleyrodids. Body dark brown to black. Marginal fringe short about 0.10 times as long as maximum width of disk (Figure 5.22:a-e).....peltata (Cockerell)
- 12b. Ovipositor plate rectangular, aleyrodid parasitoids. (Figure 5.23:k,l).....(Porteri Group).43

	66
13(9b). F1 longer than F2.....	40
13b. F1 equal to or shorter than F2, funicle segments subequal in length.....	14
14(13b). Club 3-segmented. Maxillary palps 2-segmented. Male with large oval sensorial process on F2 antennal segment (Figure 5.22:f-i) (<u>Plaumannii</u> Group). One species, mesoscutum imbricate with 14-16 pairs of setae.....	<u>plaumannii</u> Viggiani
14b. Club 2-segmented. Maxillary palps 1-segmented. Males lacking oval sensorial process. Mesoscutum with less than 10 pairs of setae. (Figure 5.20).....	<u>Inaron</u> Group.42
15(2). Gaster, axillae and scutellum pale. Head and mesoscutum dark brown with posterior 0.25 to 0.50 of mesoscutum pale and with two pairs of setae. Male F2 antennal segment longer than F3 (Figure 5.6:b;5.7:c,d,h)	<u>nigriceps</u> Dozier
15b. Gaster, axillae, head and mesoscutum dark brown. Scutellum pale to bright yellow, mesoscutum with 2 to 4 pairs of setae.....	16
16(15b). F1 short, about 0.5 times as long as F2. Mesoscutum with 2 pairs of setae (Figure 5.6:a;5.7:b,g). Males unknown.....	<u>cubensis</u> Gahan
16b. F1 and F2 subequal in length. Mesoscutum with 3 pairs of setae. Male F2 shorter than F3 segment (Figure 5.6:c;5.7:a,e,f,i)....	<u>quaintancei</u> Howard

67

- 17(2b). Entire body yellow to orange (sometimes dusky).....18
- 17b. At least head and thorax dark brown to black, gaster variable.....19
- 18(17). F1 about 0.5 times as long as F2 (Figure 5.8:l). Hind femur fuscous.
Marginal fringe about 0.10 as long as maximum disk width.
.....haitiensis Dozier
- 18b. F1 length slightly shorter than F2. Hind femur pale. Marginal fringe more
than 0.2 times as long as maximum width of disk (Figure 5.28:i-k).
.....meritoria Gahan
(E. gallardoi Marelli is indistinguishable from E. meritoria based on
Marelli (1933) description and figures).
- 19(17b). Gaster dark brown or black, not banded.....20
- 19b. Gaster pale or sometimes banded.....21
- 20(19). Club 3-segmented and distinctly clavate. Mesoscutum with 4 pairs of
setae. Marginal vein short about 0.5 times as long as disk. Ovipositor as
long as hind tibia (Figure 5.8:a,b).....brunnea Howard
- 20b. Club 2-segmented (not distinctly clavate). Mesoscutum with 9 pairs of
setae. Marginal vein about equal to disk length. Ovipositor 1.14 as long
as midtibia (Figure 5.9:a-e).....guadeloupae Viggiani
- 21(19b). Gaster with brown transverse or lateral bands. Midtibial spur long, about
equal to corresponding basitarsus. F1 short less than 1.5 times as long

	68
as wide (Figure 5.5:k).....	22
21b. Gaster pale, midtibial spur short, only 0.50 to 0.75 as long as basitarsus	
II. F1 elongate at least two times as long as wide (Figure 5.8:h).....	23
22(21). F1 about 0.5 times as long as F2. Lateral margin of tergites I-VII with dark brown markings. Head and mesoscutum dark brown. Scutellum pale with anterior margin dark brown. Forewing disk broad with rounded apex (Figure 5.10:a).....	<u>variegata</u> Howard
22b. F1 only slightly shorter than F2. Tergites V and VI with brown transverse bands. Head, mesoscutum and scutellum lighter brown, midtibial spur longer and forewing disk not as broad or apex as rounded as in above species (Figure 5.8:c-e).....	<u>desantisi</u> Viggiani
23(21b). Head and thorax dark brown, gaster bright yellow. Linear sensillae present on F1 and F2. Interior of mesoscutum and axillae areolate rather smooth. Males rare and with scutellum dark brown (Figure 5.8:f,g).	
.....	<u>formosa</u> Gahan
23b. Head and thorax light brown to dark orange, gaster pale yellow. Linear sensillae absent on F1 and F2. Interior of mesoscutum and axillae areolae with rugose lines. Males common and with light brown scutellum (Figure 5.10:b,c).....	<u>luteola</u> Howard

- 24(5b). Mesoscutum with inverted brownish triangle spot and with more than 3 to 4 pairs of setae (Figure 5.11:c-e).....pergandiella Howard
- 24b. Mesoscutum color uniform with 2 pairs of setae.....25
- 25(24b). Base of gaster with prominent, dark transverse band. F1 short about equal to 0.5 times the length of F2 (Figure 5.11:f-h).....basicincta Gahan
- 25b. Gaster uniform in color. F1 and F2 subequal in length.....26
- 26(25b). Valvular III apical setae lanceolate. Forewing setae very sparse (large bare areas on anterior and posterior margins) (Figure 5.12).
.....lanceolata spec. nov.
- 26b. Valvular III apical setae slender. Forewing setae more profuse (Figure 5.11:a,b).....americana DeBach and Rose
- 27(8). Forewing with infuscate band under the marginal vein. Tergites III-V with transverse bands or spot (Figure 5.14:a).....28
- 27b. Forewing hyaline. Gaster yellow or orange, not banded.....29
- 28(27). Transverse bands of gaster very well defined and reaching lateral margins. Funicle segments increasing in length. Valvular III moderate in length about two times as long as wide, basitarsus II very short less than length of midtibial spur (Figure 5.14a-e).....citrella (Howard)
- 28b. Dark spot in center of gaster with margins not well defined. Funicle

segments subequal in length. Valvular III very short, about as long as wide. Basitarsus II moderate length longer than tibial spur (Figure 5.15:a-d).....pseudocitrella spec. nov.

- 29(27b). Forewing posterior margin with small area of long coarse setae. Occiput rugose. F6 elongate longer than F4 or F5, conical setae on basitarsus II absent. Ovipositor moderate in length, less than or equal to length of midtibia, syntergum not elongate. Five basal setae not extending mesially beyond smv 2 setae. Midtibial spur distinctly shorter than basitarsus II (Figure 5.13:g-j).....transvena (Timberlake)
- 29b. Forewing setae uniform (without area of long coarse setae). Occiput reticulate. F6 shorter than F4 or F5. Row of conical setae on basitarsus II (Figure 5.13:c,f). Ovipositor much longer than midtibia and syntergum elongate. Forewing with 7-8 basal setae extending mesially beyond smv2 setae. Midtibial spur about equal to length of basitarsus II.....31
- 30(29b). Ovipositor more than 1.7 times as long as midtibia. F6 conical about equal to F5 with F4 longer than F5. Basitarsus II with 2-3 conical setae, axilla setae elongate reaching almost to base of axilla (Figure 5.13: a-c).....armata (Silvestri)
- 30b. Ovipositor less than 1.7 times as long as midtibia, F6 short and stubby with F5 longer than F4. Axilla setae shorter than in former species, not reaching axilla base. Basitarsus II with row of 5 large conical setae.

- (Figure 5.13:d-f).....*strenua* (Silvestri)
- 31(7b). F1 elongate, about 3 times as long as wide, longer than pedicel and
subequal to other funicle segments. Thorax yellow (Figure 5.16:
e-f).....*lycopersici* De Santis
- 31b. F1 short, less than 2 times as long as wide and shorter than pedicel,
color variable.....32
- 32(31b). Forewing hyaline, funicle uniform in color F4 shorter than F5. Midtibial
spur about equal to basitarsus II. Five pairs of mesoscutal setae.
Ovipositor robust originating at base of the gaster (Figure 5.16:a-c).
.....*portoricensis* Howard
- 32b Forewing infuscate, F5 and/or F6 brown, contrasting with yellow
F1-F4.....33
- 33(32). Mesoscutum dark brown. F1 cylindrical, subequal to length of pedicel.
Antennae yellow with scape and F6 antennal segments brown. Hind
coxae and femur dark brown. Axilla setae located centrally. Ovipositor
shorter than midtibia (Figure 5.16:g-i).....*quercicola* (Howard)
- 33b. Mesoscutum orange. Antennae yellow, F5 and F6 brown, pedicel short,
less than length of F1. Axilla setae at apex of axilla. Hind coxae pale and
ovipositor longer than midtibia (Figure 5.17:f-h).....*catherinae* Dozier

- 34(10b). Gaster completely brown to dark brown (tergum VII may be lighter), forewing hyaline (except in smithi).....35
- 34b. Gaster not completely brown, at least one other tergum yellow. Forewing infuscate.....37
- 35(34). F1 and F2 short, quadrate and subequal in length, each about 0.5 times as long as F3. Tergum VI with spiracular plates distinctly separated. Head and thorax yellow with axillae dark brown (Figure 5.5.19:a-d).
.....merceri Silvestri
- 35b. At least F2 cylindrical more than 0.5 times as long as F3. Tergum VI spiracular plates not separated. Color variable.....36
- 36(35b) F1 usually wider than long and less than 0.5 times as long as F2. Forewing hyaline. Axilla setae locate centrally. Syntergum elongate, ovipositor strongly exserted.....37
- 36b. F1 longer than wide, and more than 0.5 times as long as F2. Forewing infuscate. Syntergum not elongate and ovipositor not strongly exserted. (Figure 5.19:e,f).....smithi (Silvestri)
- 37(34b). Ovipositor as long as midtibia. Marginal fringe about 0.25 times as long as maximum disk width. Stigmal vein with narrow neck. Ovipositor not extruded (Figure 5.18:c-f).....divergens (Silvestri)

- 37b. Ovipositor longer than midtibia. Marginal fringe less than 0.20 times as long as maximum disk width. Stigmal vein neck not narrow. Syntergum elongate and ovipositor extruded.....39
- 38(37b). Clypeus with triangular projection. Mesoscutum with 10 setae. Basal half of mid femur and entire hind femur dark brown. Sc1 setae relatively short, not reaching base of Sc2 setae (Figure 5.19:g-l).....clypealis (Silvestri)
- 38b. Clypeus lacking triangular projection. Mesoscutum with 8 setae. Femur II and III orangish. Sc 1 setae very long and stout, reaching the base of Sc 2 setae (Figure 5.18:a,b).....townsendi Howard
- 39(37b). Gaster dark brown with tergum VII (sometimes I and II) yellow. Mesoscutum with 10 pairs of setae and small hexagonal areolae in a spiral design. Valvular III yellow with distal half dark brown. Midtibial spur large about as long as basitarsus II (Figure 5.18:g-k)....opulenta (Silvestri)
- 39b. Gaster dark brown with tergum IV-VI dark, other characters similar to opulenta (Figure 5.17:a-e).....brasiliensis (Hempel)
- 40(13). Mesoscutum with two pairs of setae and areolae arranged in a dome-shaped pattern. Sc1 setae minute. Forewing uniformly setose with bare strip along the posterior margin (Figure 5.21:a-d).....lahorensis (Howard)
- 40b. Mesoscutum very setose (11 pairs of setae) with areolae in longitudinal rows. Sc1 setae long. Forewing setae under the marginal vein longer and coarser than disk setae.....ciliata (Gahan)

- 41(14b) Gaster entirely dark, hind femur with dark brown band in the middle.
 Ovipositor subequal in length of midtibia. Axilla setae large and stout.
 (Figure 5.20:f-i).....coquillettii Howard
- 41b. Gaster pale (sometimes banded), hind femur without dark brown band.
 Ovipositor shorter than midtibia. Axilla setae not particularly large and
 stout.....42
- 42(41b) Gaster pale (may have transverse bands on tergum V and VI), head,
 mesoscutum and scutellum dark brown. Tergites II-IV imbricated with 1
 pair of lateral setae, all funicle segments subequal in length (Figure 5.20:
 a-c).....inaron (Walker)
- 42b. Gaster yellowish with central area of tergites IV-VII brownish. Tergites II-
 IV imbricate with 3 pairs of setae. Mesoscutum brown with lateral margins
 yellowish. F2 and F4 longer than F3 and F5, respectively (Figure 5.20:
 d-f).....lopezi Blanchard
- 43(12b) Body yellow. Basitarsus II elongate about 6-7 times as long as wide.
 (Figure 5.23:k-m).....porteri (Mercet)
- 43b. Body yellow, with central region of mesoscutum with large, round dark
 brown spot, lateral margins of gaster dark brown (Figure 5.24:a-e)
polaszeki spec. nov.

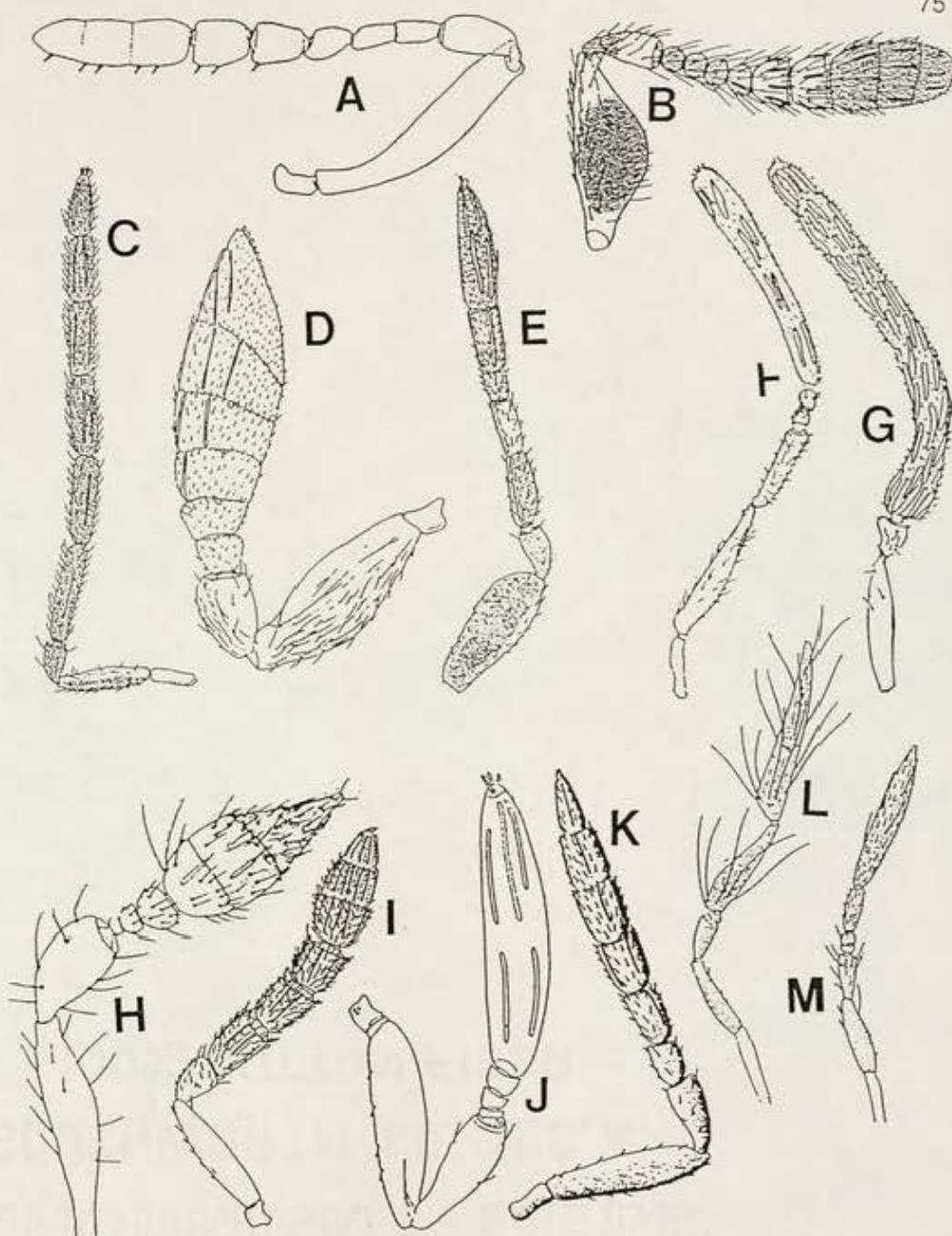


Figure 5.1. Parasitoid Antennae. A) ♀ Amitus B) ♀ Metaphycus C) ♀ Encarsiella
D) ♀ Dirphys E) ♀ Azotus F) ♀ Eretmocerus G) ♂ Eretmocerus
H) ♀ Euderomphale I) ♀ Coccophagus J) ♀ Signiphora
K) ♀ Coccophagoides L) ♂ Cales M) ♀ Cales.

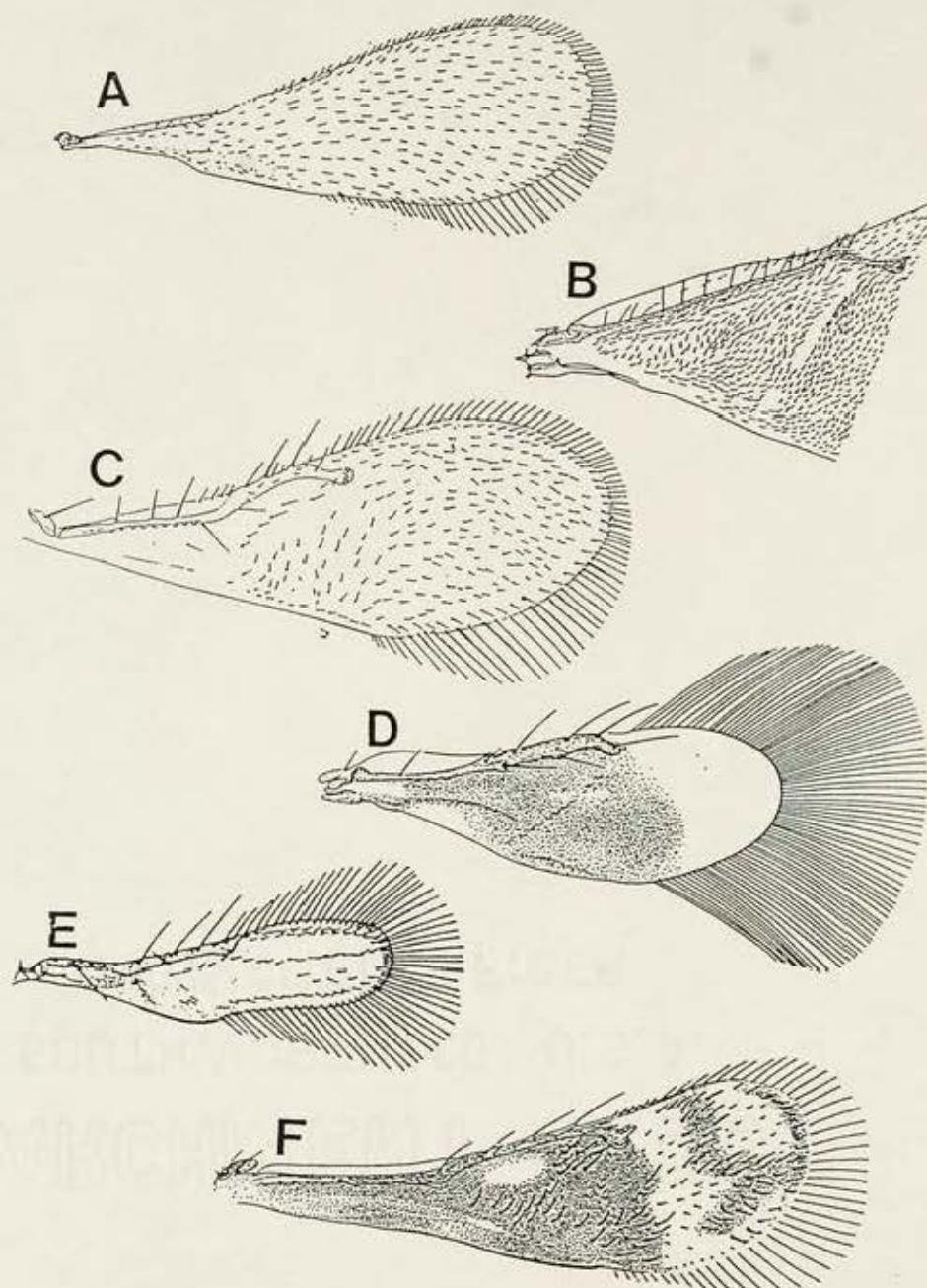


Figure 5.2. Forewing ♀ A) Amitus B) Metaphycus C) Eretmocerus
D) Signiphora E) Cales F) Azotus.

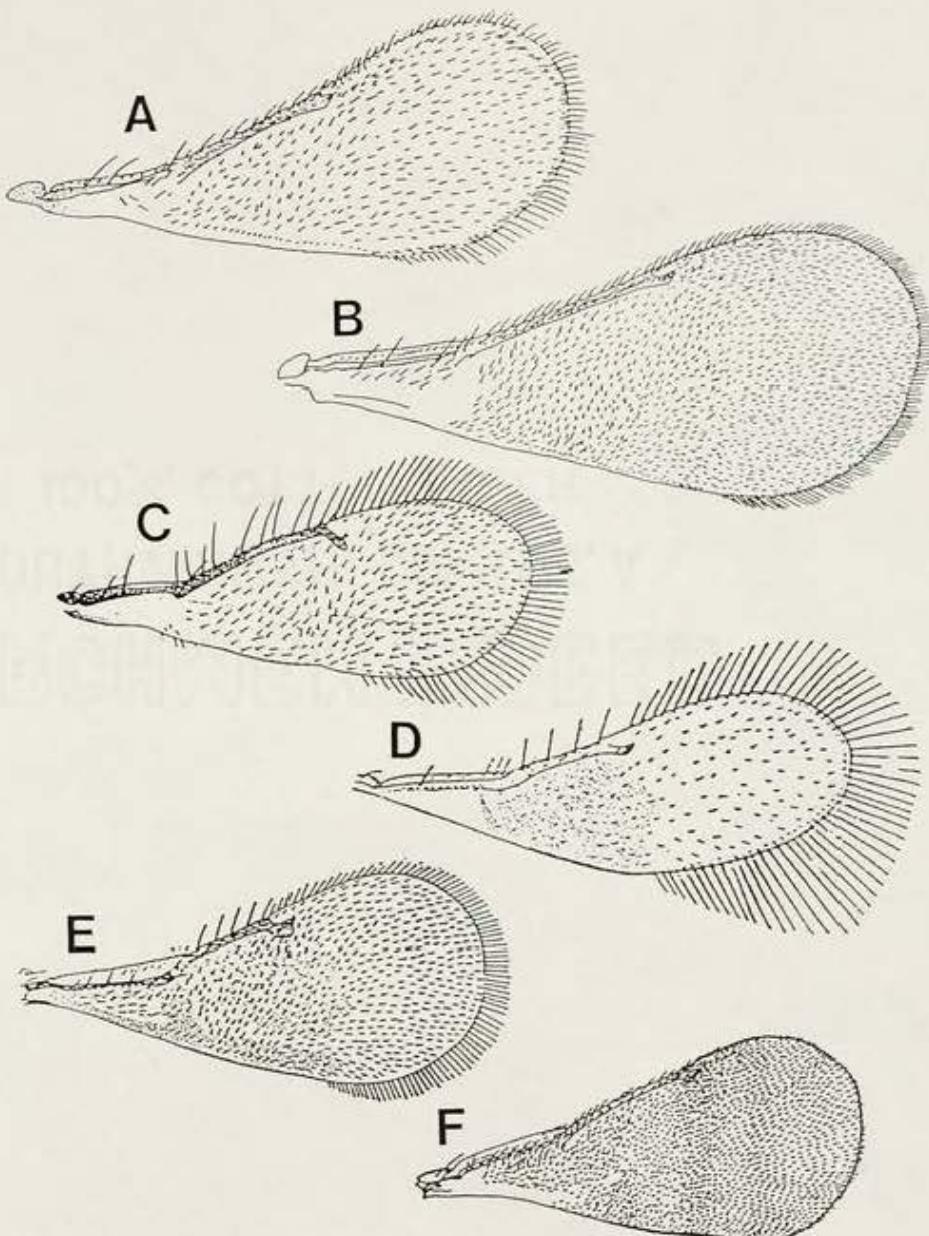


Figure 5.3. Forewings ♀. A) Dirphys B) Encarsiella C) Euderomphale
D) Pteroptrix E) Coccophagooides F) Coccophagus.

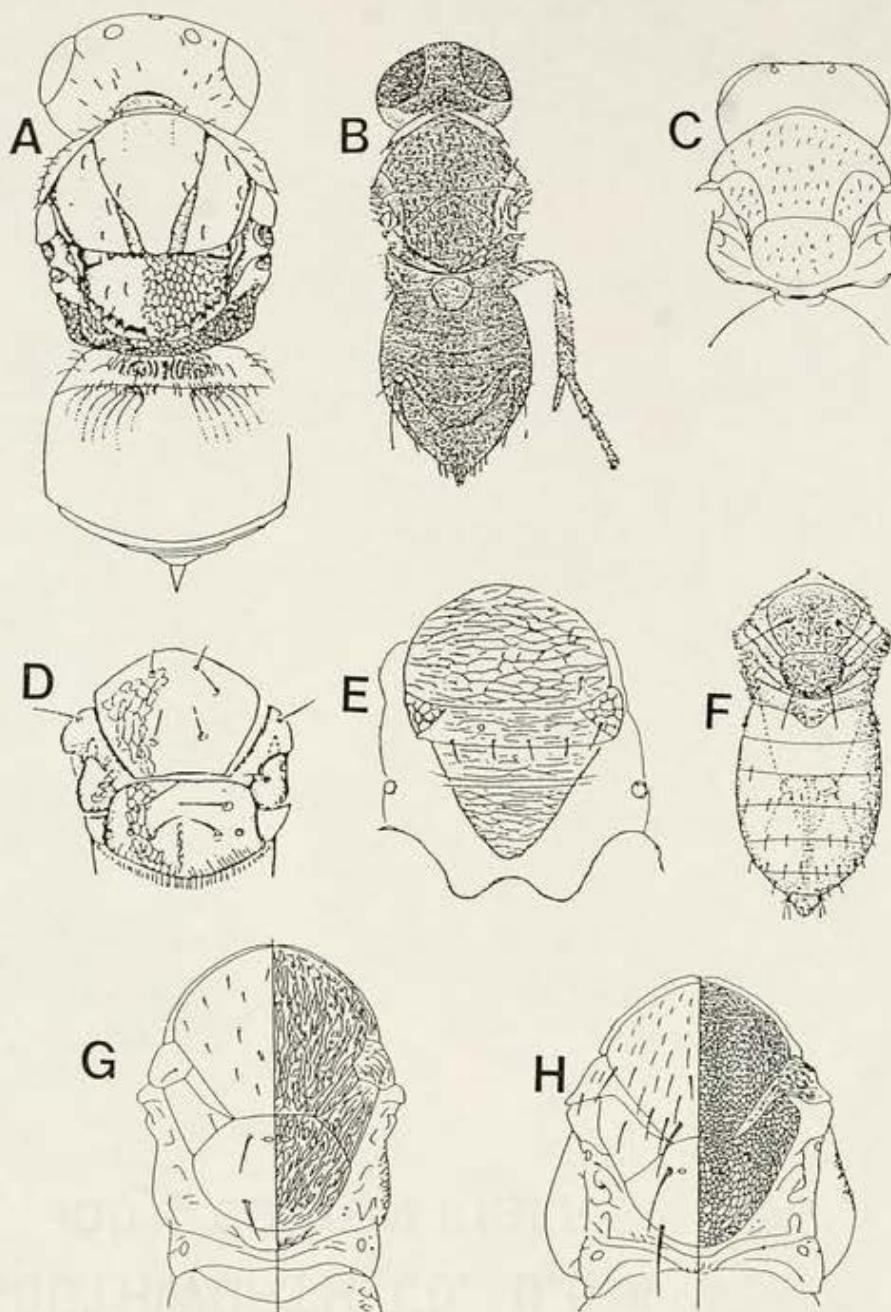


Figure 5.4. ♀ Thorax. A) Amitus B) Metaphycus C) Euderomphale
D) Eretmocerus E) Signiphora F) Cales
G) Dirphys H) Encarsiella

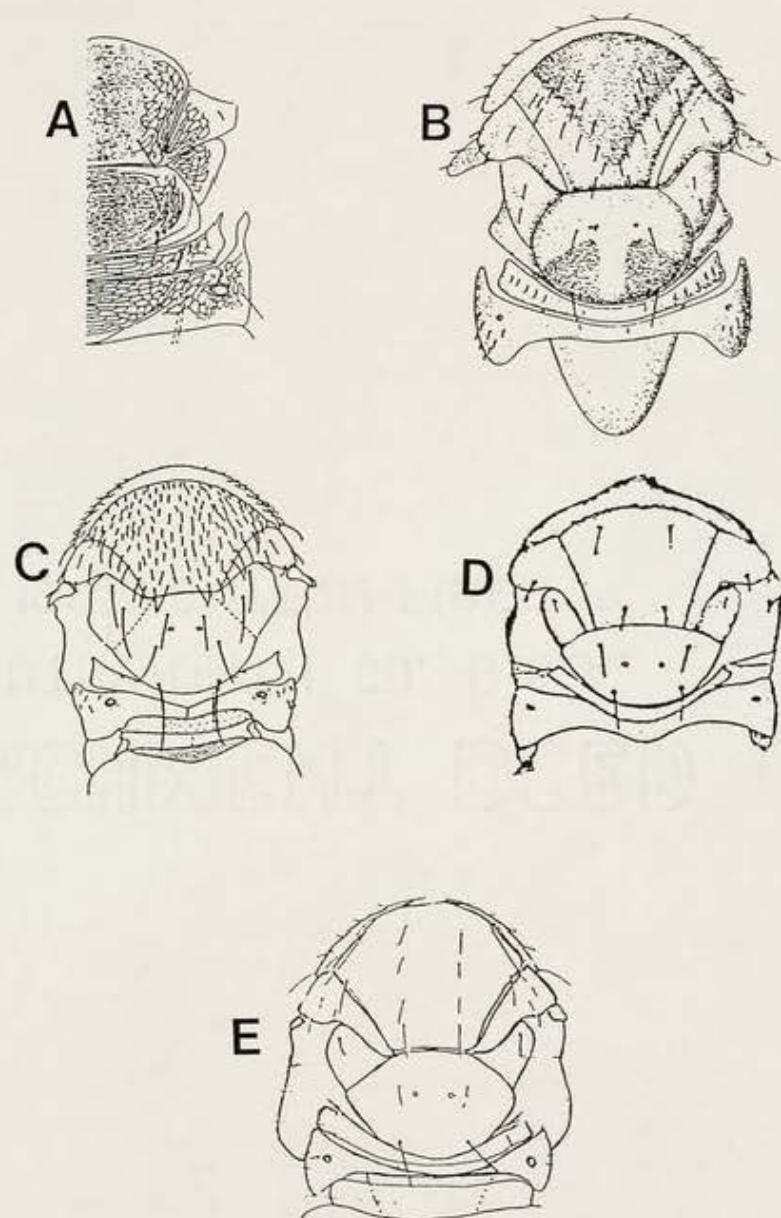


Figure 5.5. ♀ Thorax. A) Azotus B) Coccophagoides C) Coccophagus
D) Pteroptrix E) Encarsia.

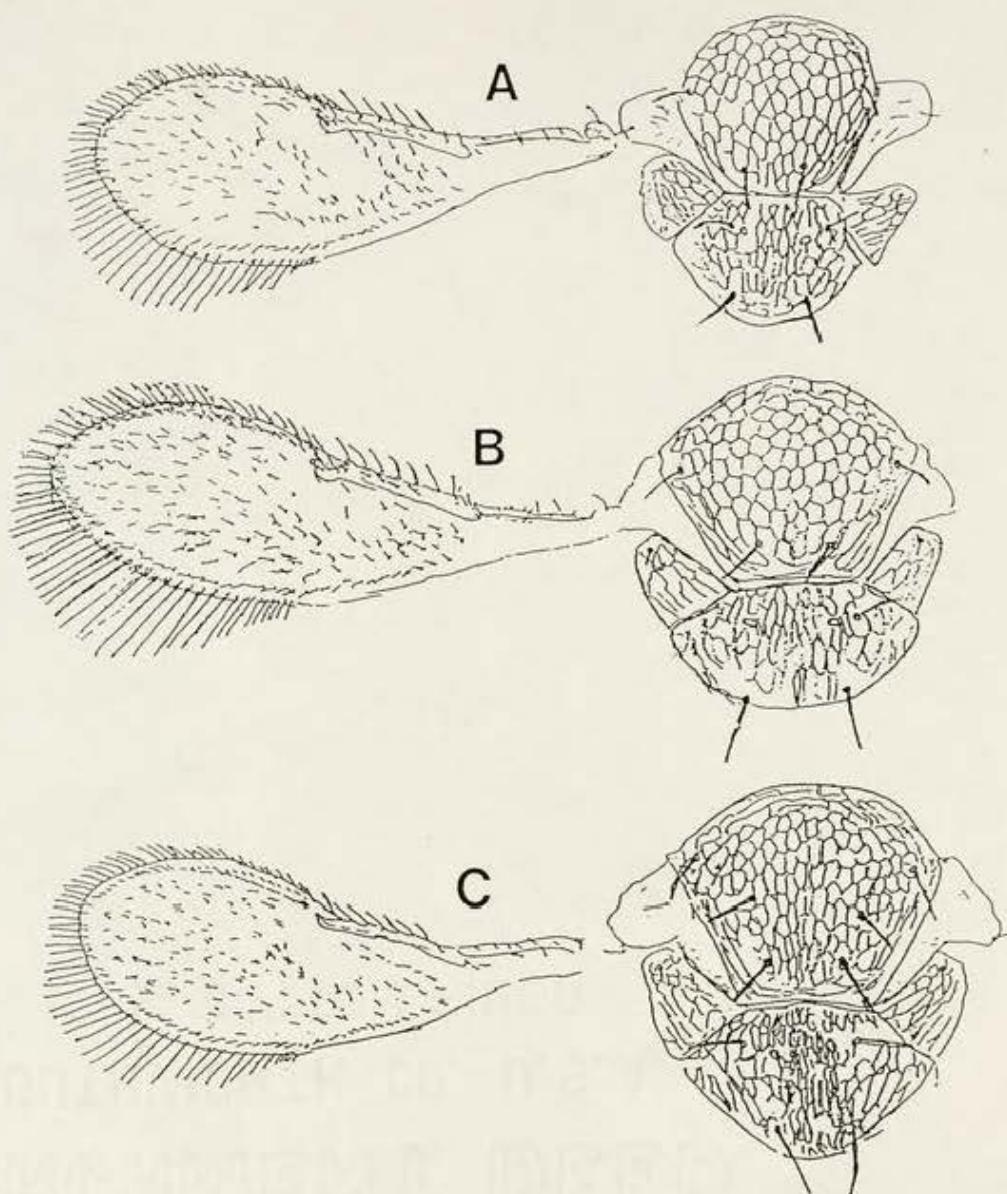


Figure 5.6. ♀ Forewing and Mesothorax. A) cubensis B) nigriceps C) quaintancei.

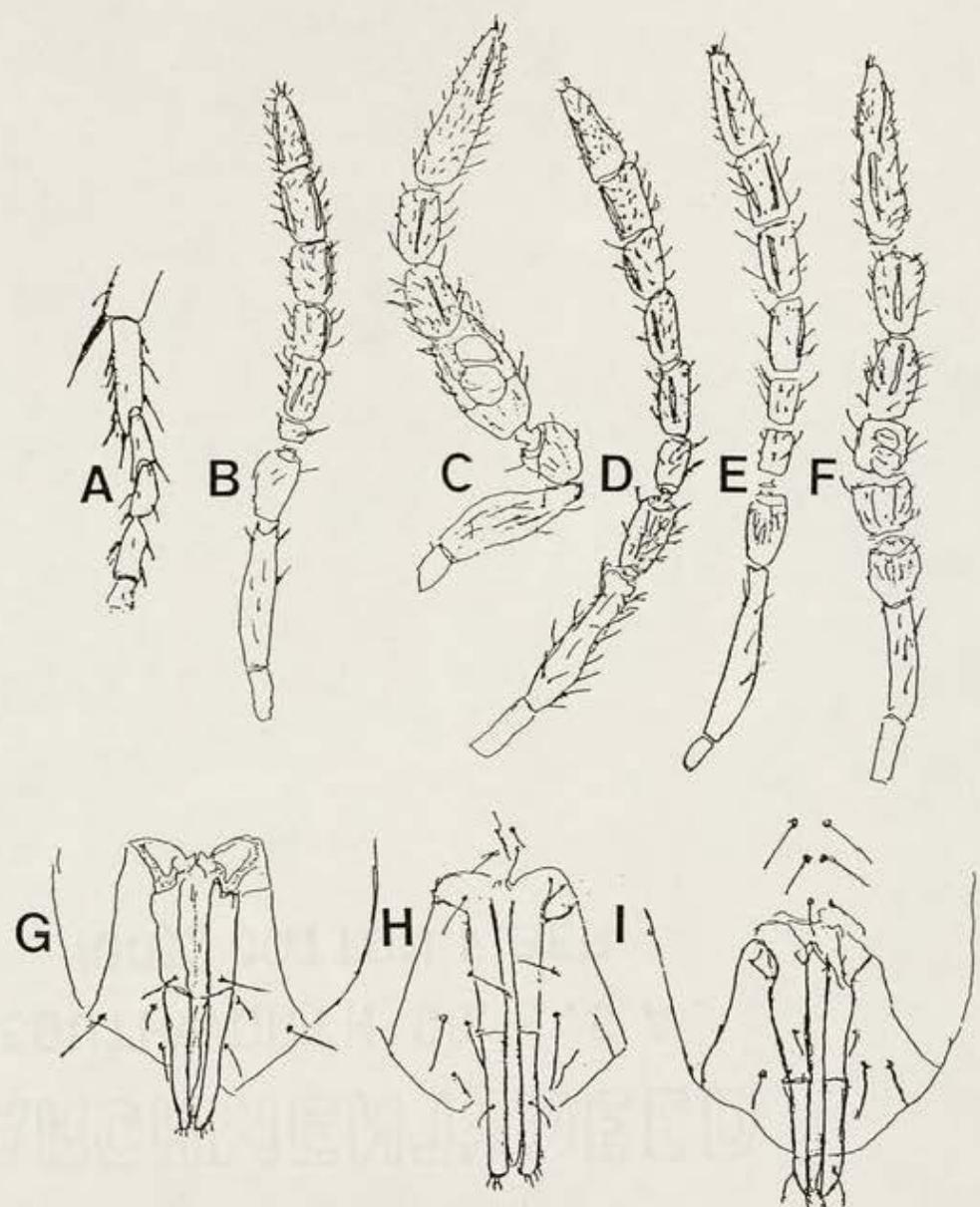


Figure 5.7. A) quaintancei ♀ midtarsus. B-G Antennae. B) ♀ cubensis
C) ♂ nigriceps D) ♀ nigriceps E) ♀ quaintancei
F) ♂ quaintancei. G-I ovipositor. G) cubensis H) nigriceps
I) quaintancei.

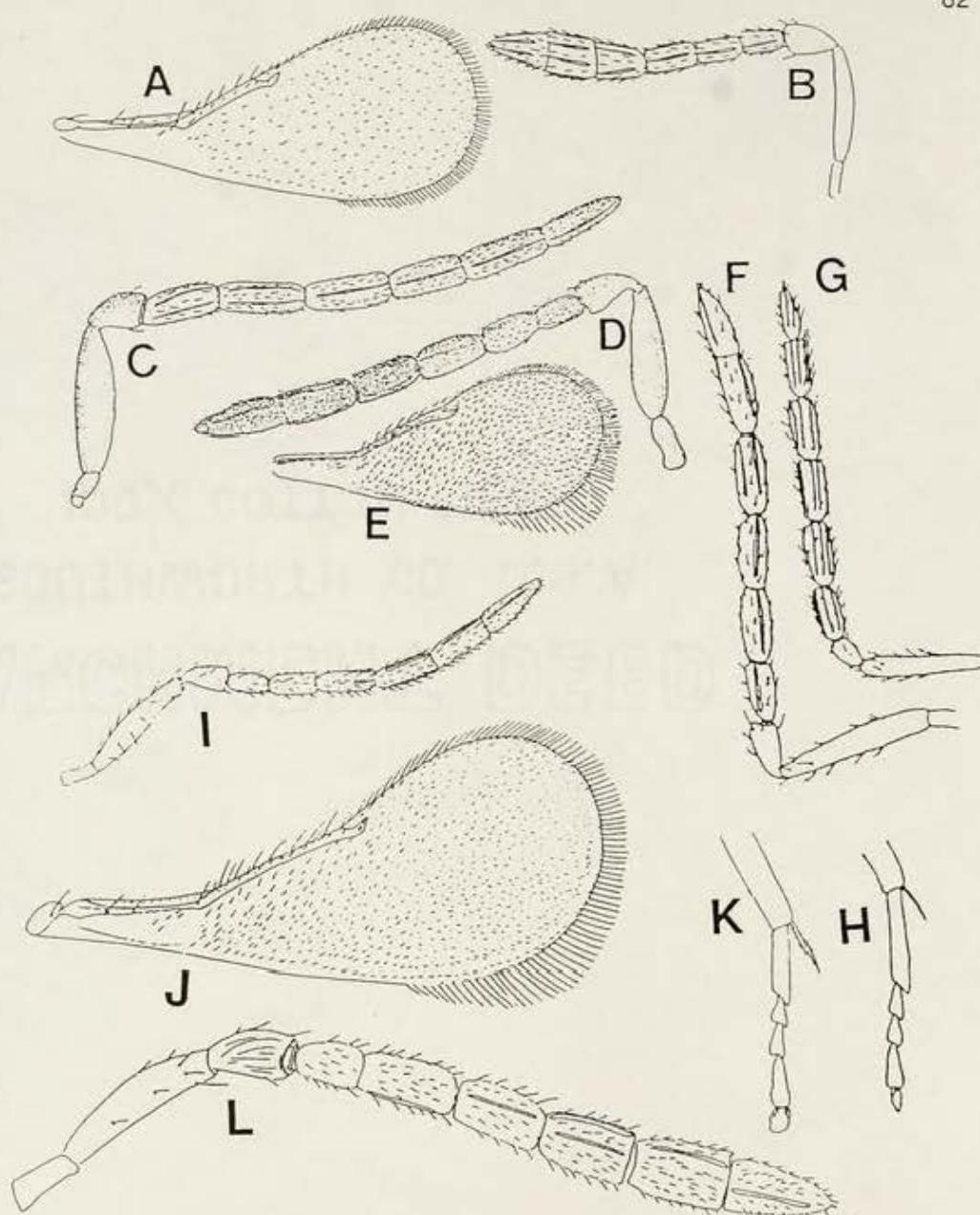


Figure 5.8. *E. brunnea* A) ♀ forewing B) ♀ antenna. *desantisi* C) ♀ antenna D) ♂ antenna E) ♀ forewing. *formosa* F) ♀ antenna G) ♂ antenna H) ♀ tarsus II. *meritoria* I) ♀ antenna J) ♀ forewing K) ♀ tarsus II. *haitiensis* L) ♀ antenna.

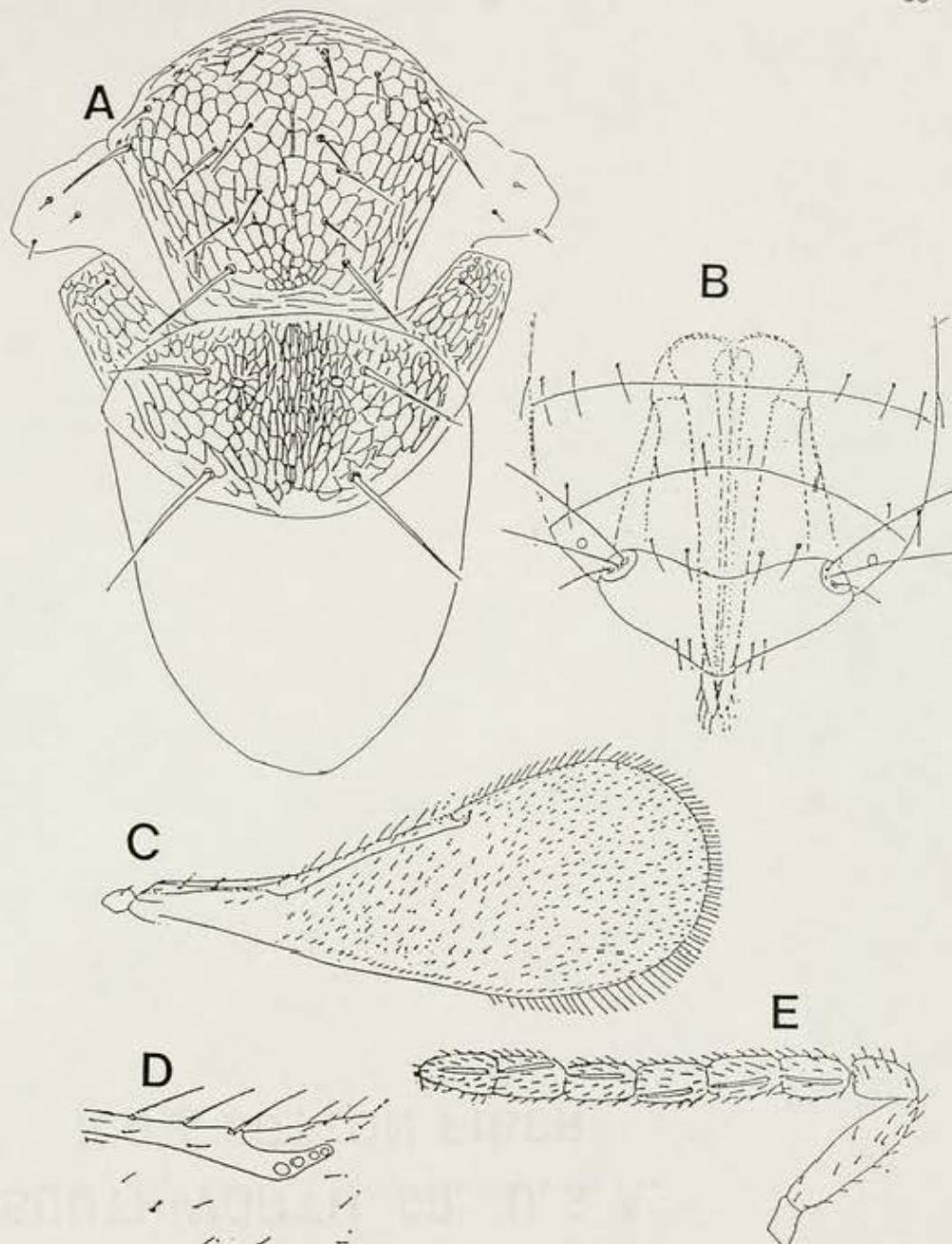


Figure 5.9. Female, Encarsia guadeloupae A) thorax B) ovipositor C) forewing
D) stigmal vein E) antenna

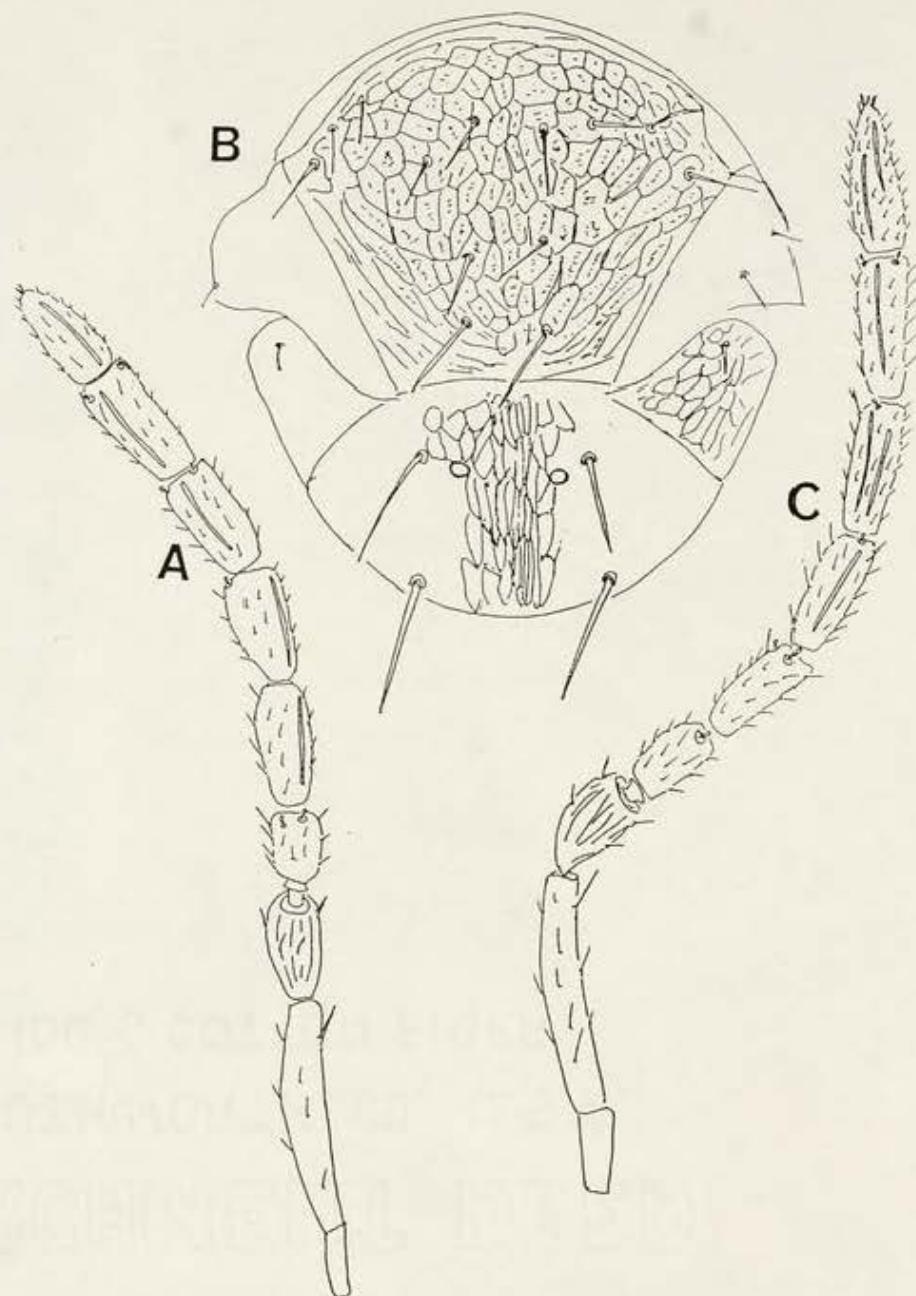


Figure 5.10. Female. Encarsia variegata A) antenna. luteola B) thorax C) antenna

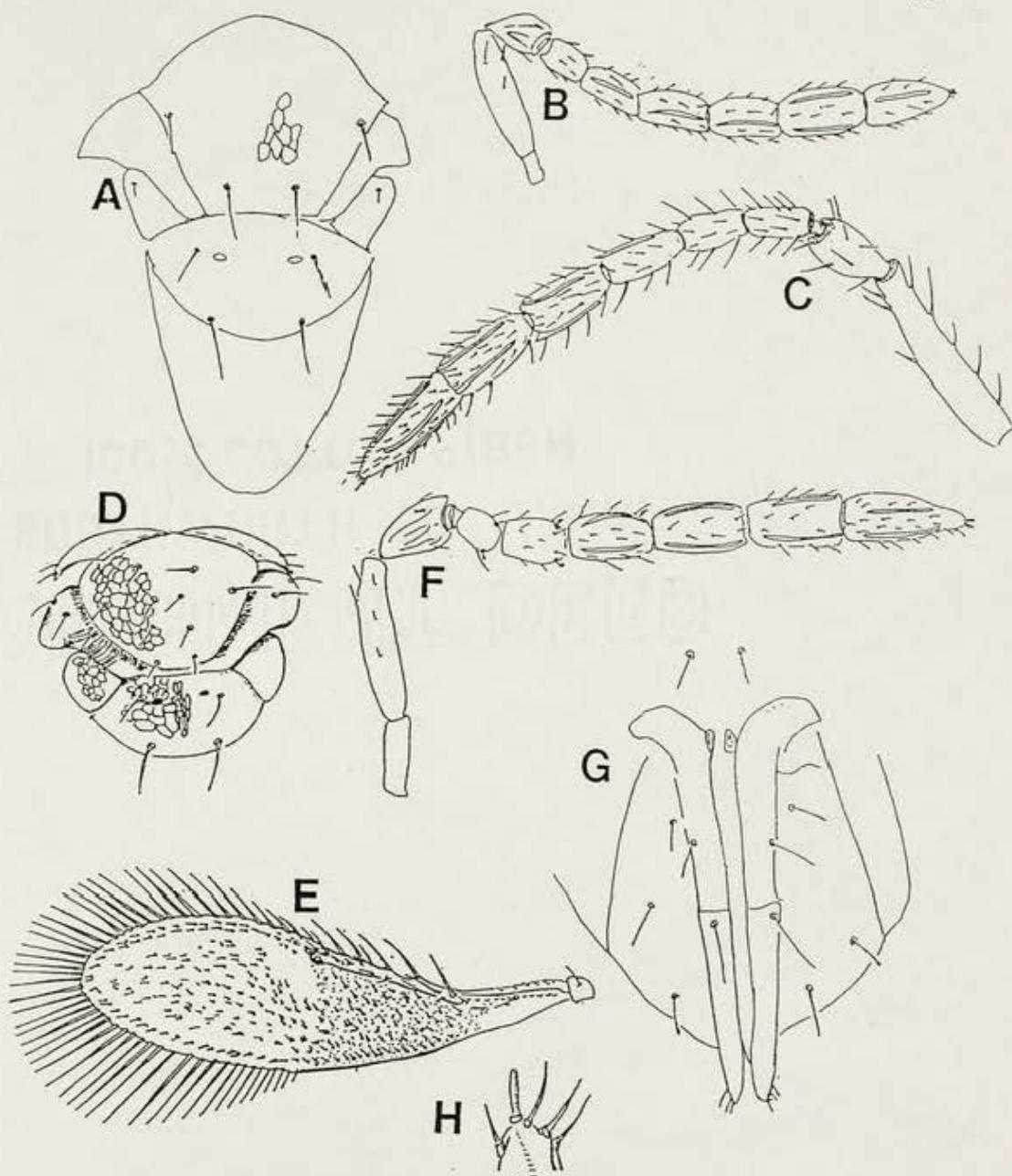


Figure 5.11. Female. *Encarsia americana* A) thorax B) antenna. *pergandiella*
G) antenna D) thorax E) forewing,*basicincta* F) antenna G) ovipositor
H) F6 antennal apex.

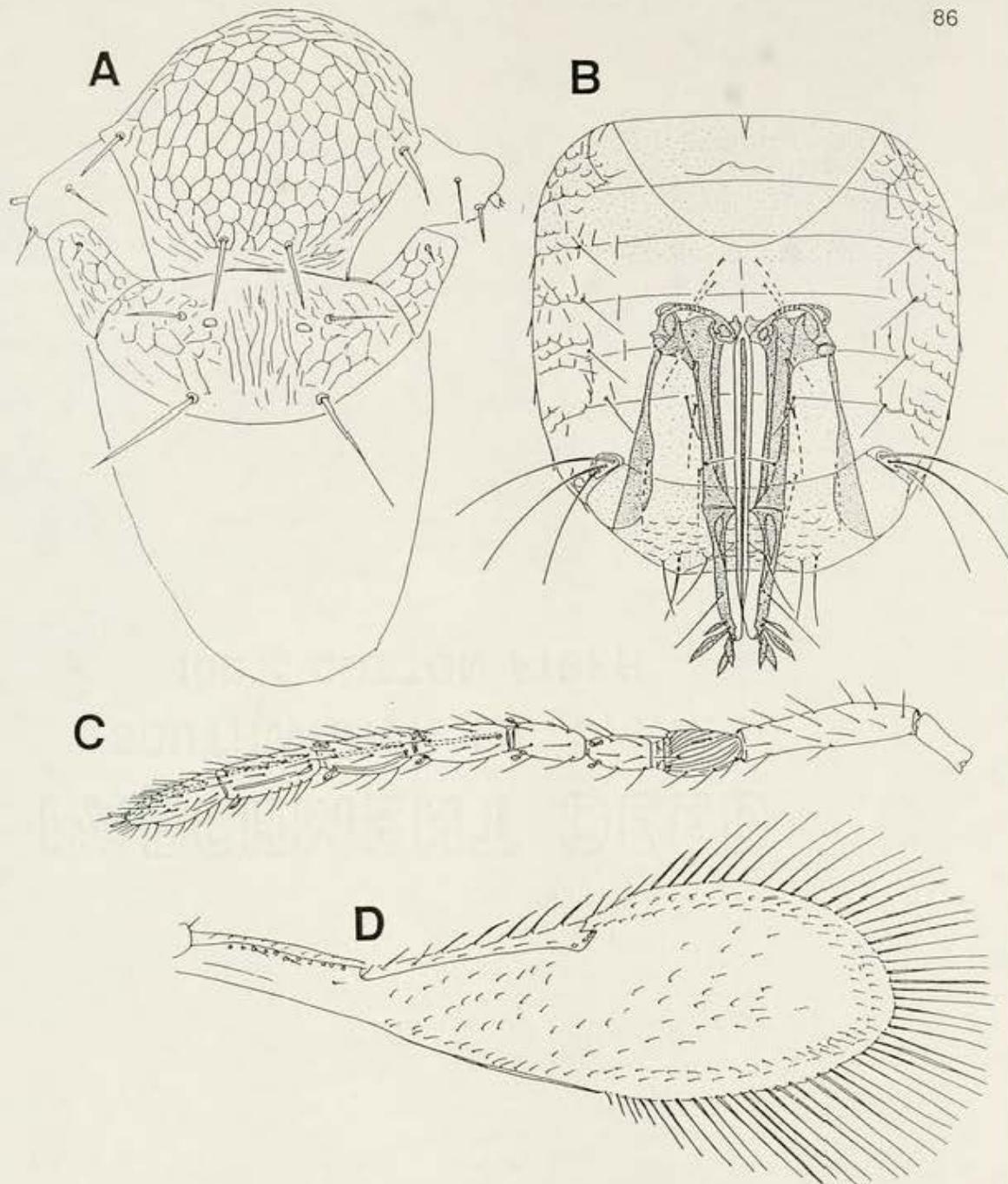


Figure 5.12. Female. *Encarsia lanceolata* A) thorax B) ovipositor C) antenna D) forewing.

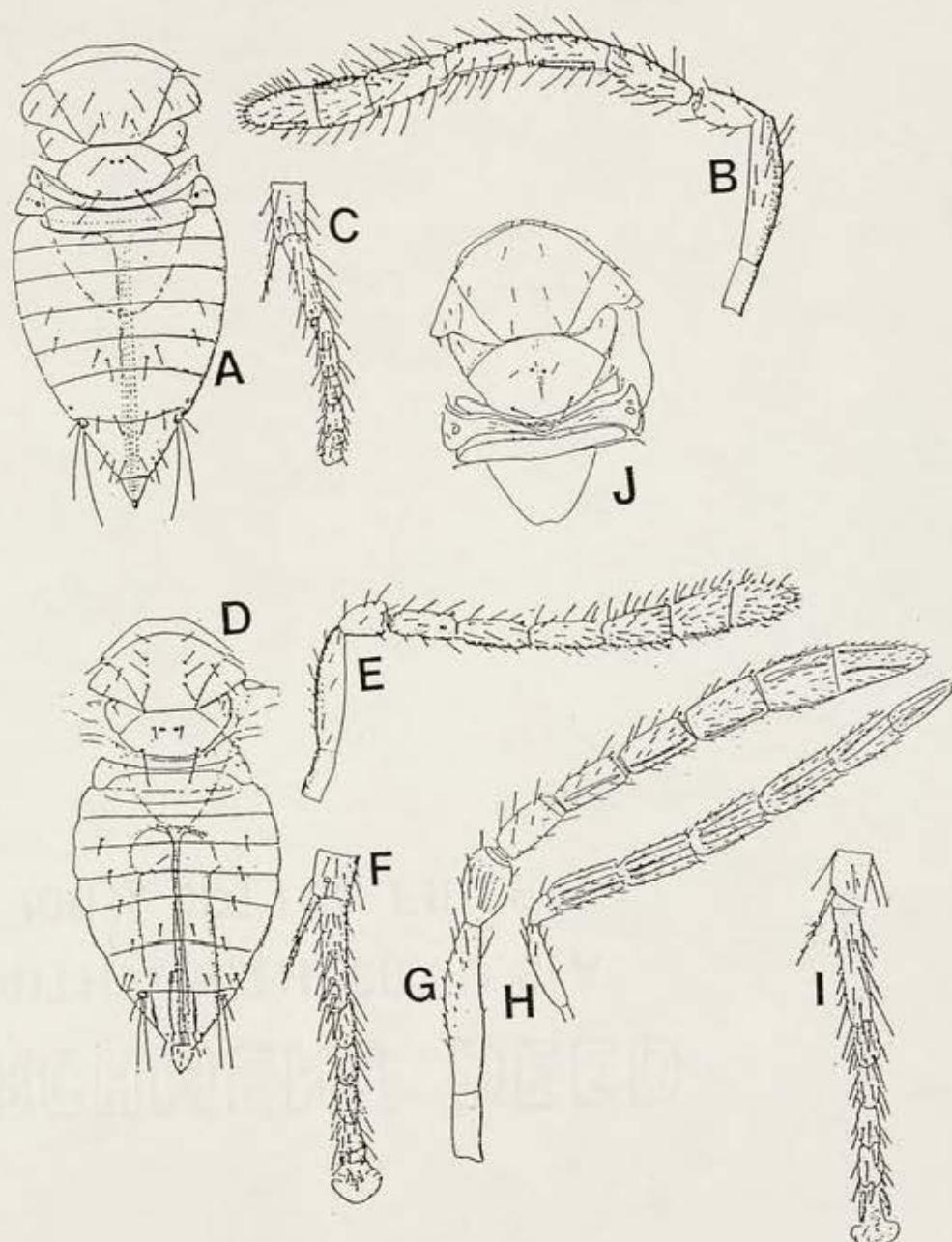


Figure 5.13. *Encarsia armata* A) ♀ habitus B) ♀ antenna C) ♀ tarsus II. *strenua*
D) ♀ habitus E) ♀ antenna F) ♀ tarsus II. transvena G) ♀ antenna
H) ♂ antenna I) ♀ tarsus II J) ♀ thorax

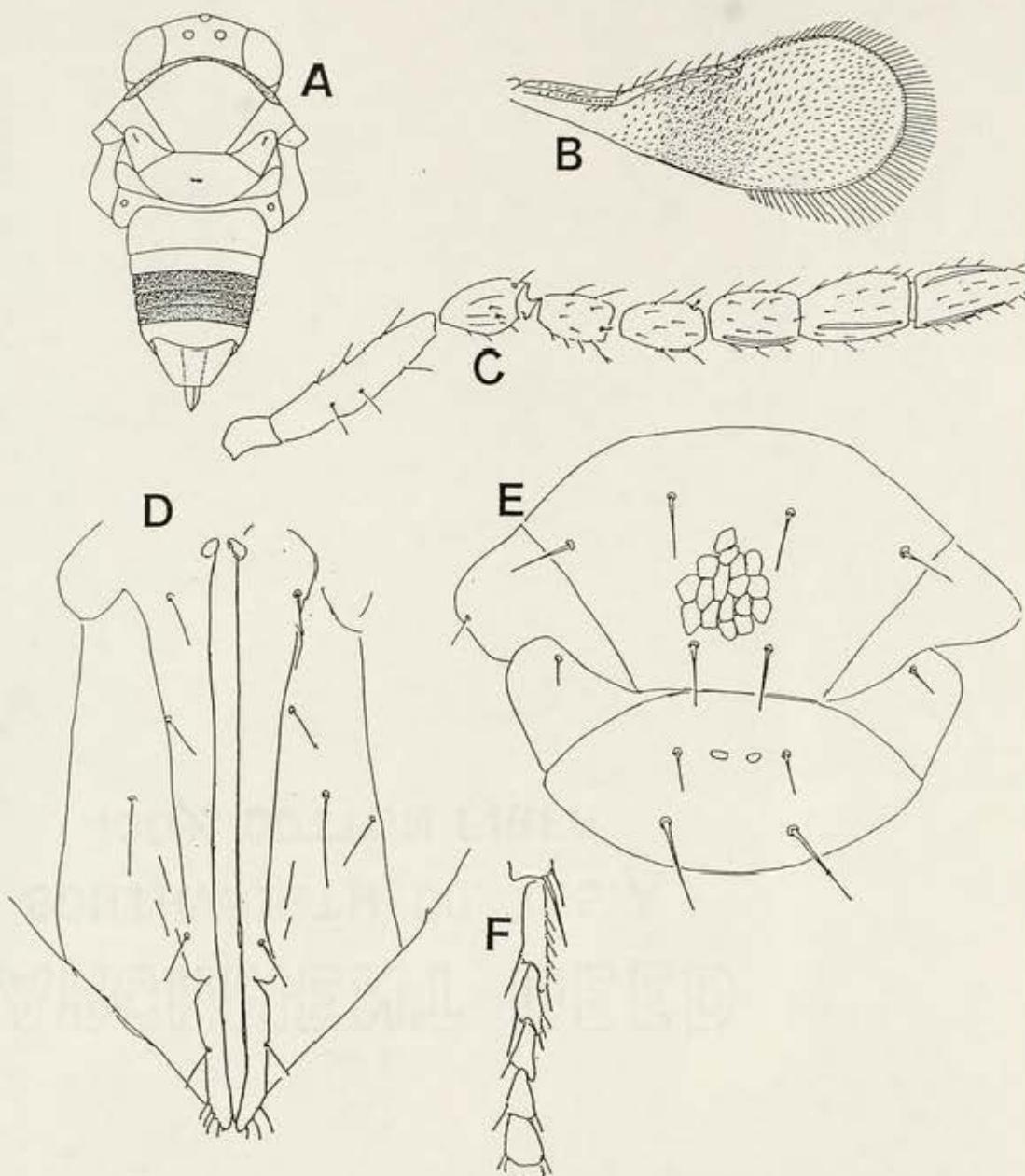


Figure 5.14. Female. *Encarsia citrella*. A) habitus B) forewing C) antenna
D) ovipositor E) thorax F) tarsus II.

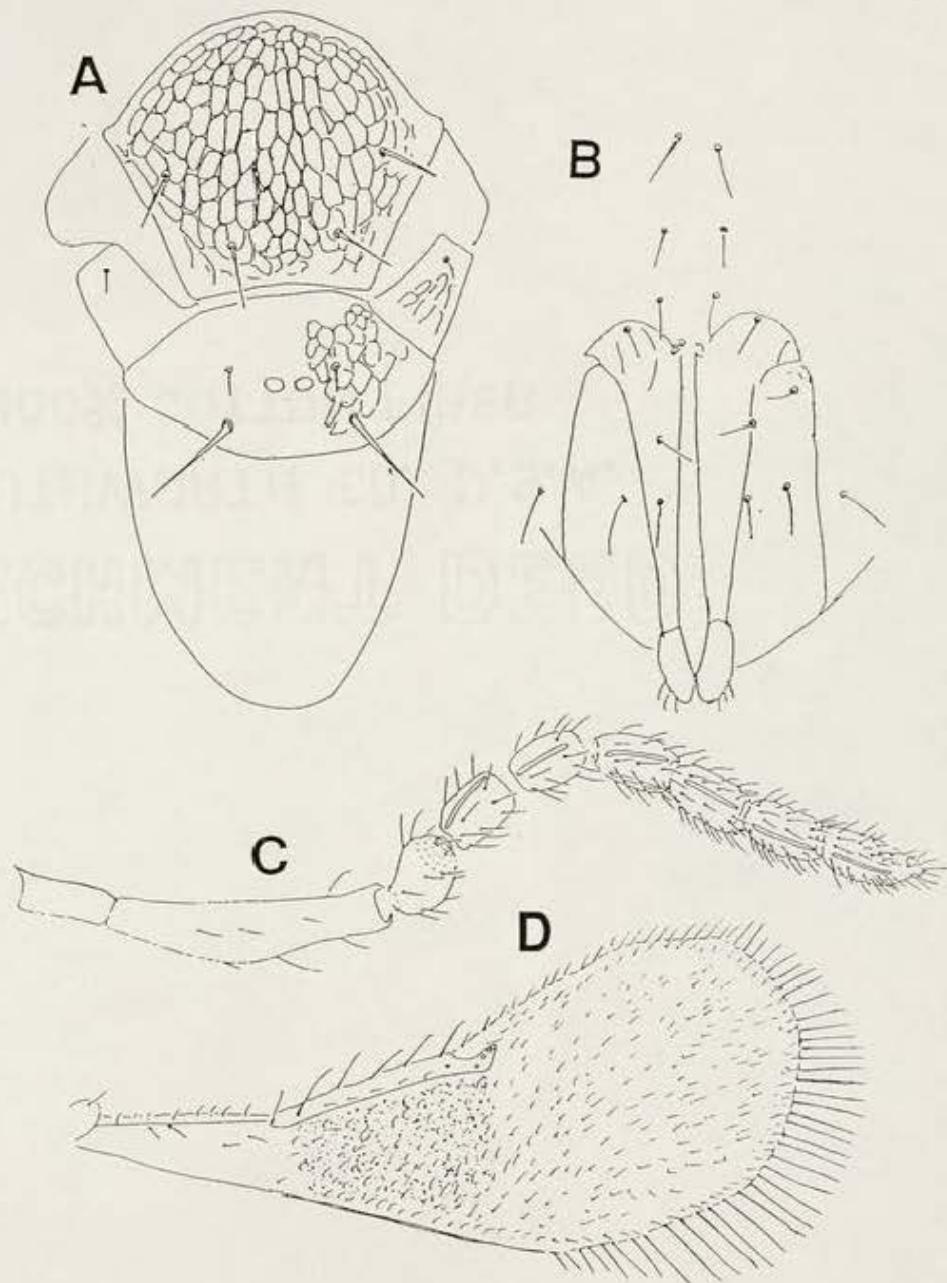


Figure 5.15. Female, *Encarsia pseudocitrella*. A) thorax B) ovipositor C) antenna
D) forewing.

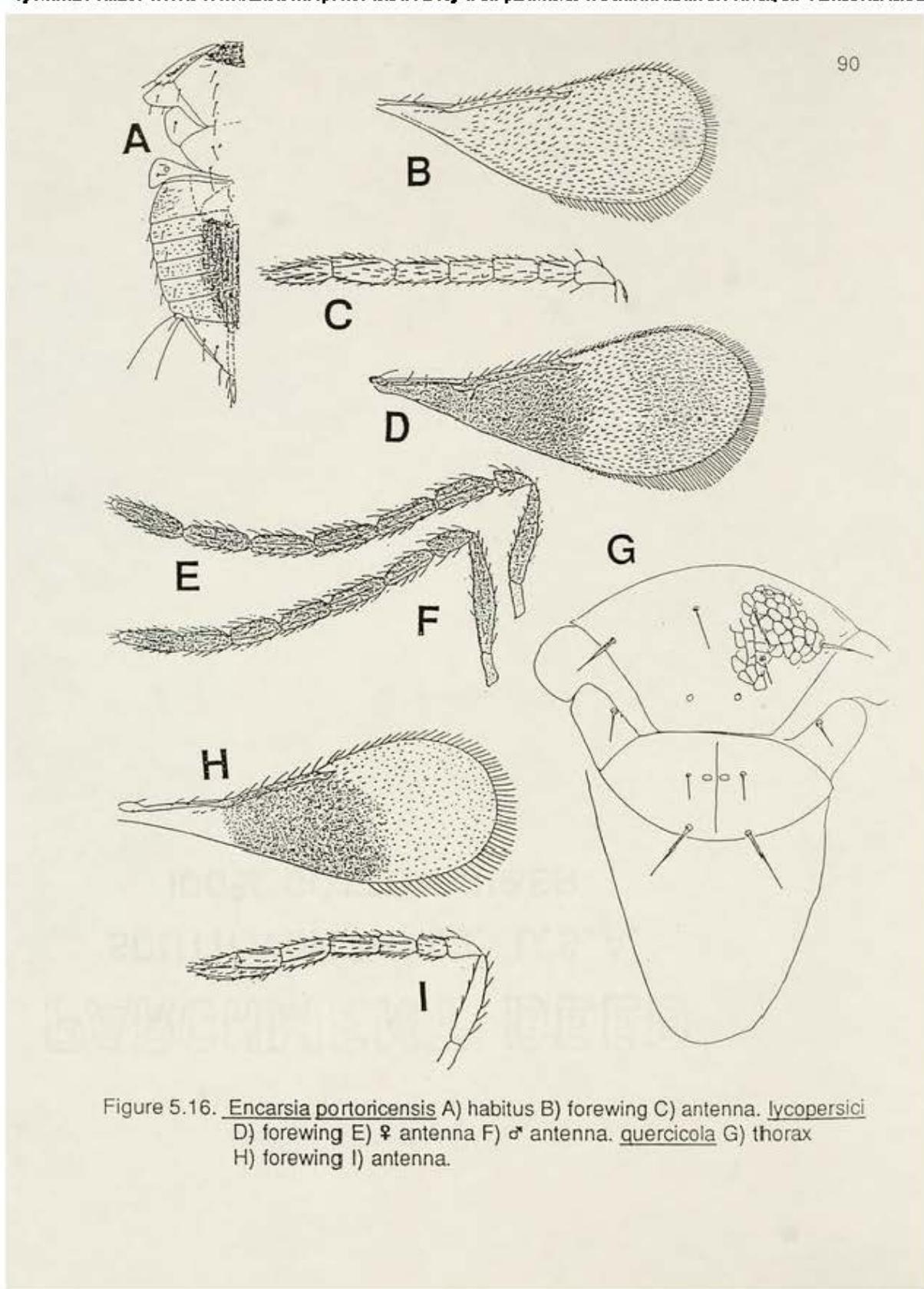


Figure 5.16. *Encarsia portoricensis* A) habitus B) forewing C) antenna. *lycopersici*
D) forewing E) ♀ antenna F) ♂ antenna. *quercicola* G) thorax
H) forewing I) antenna.

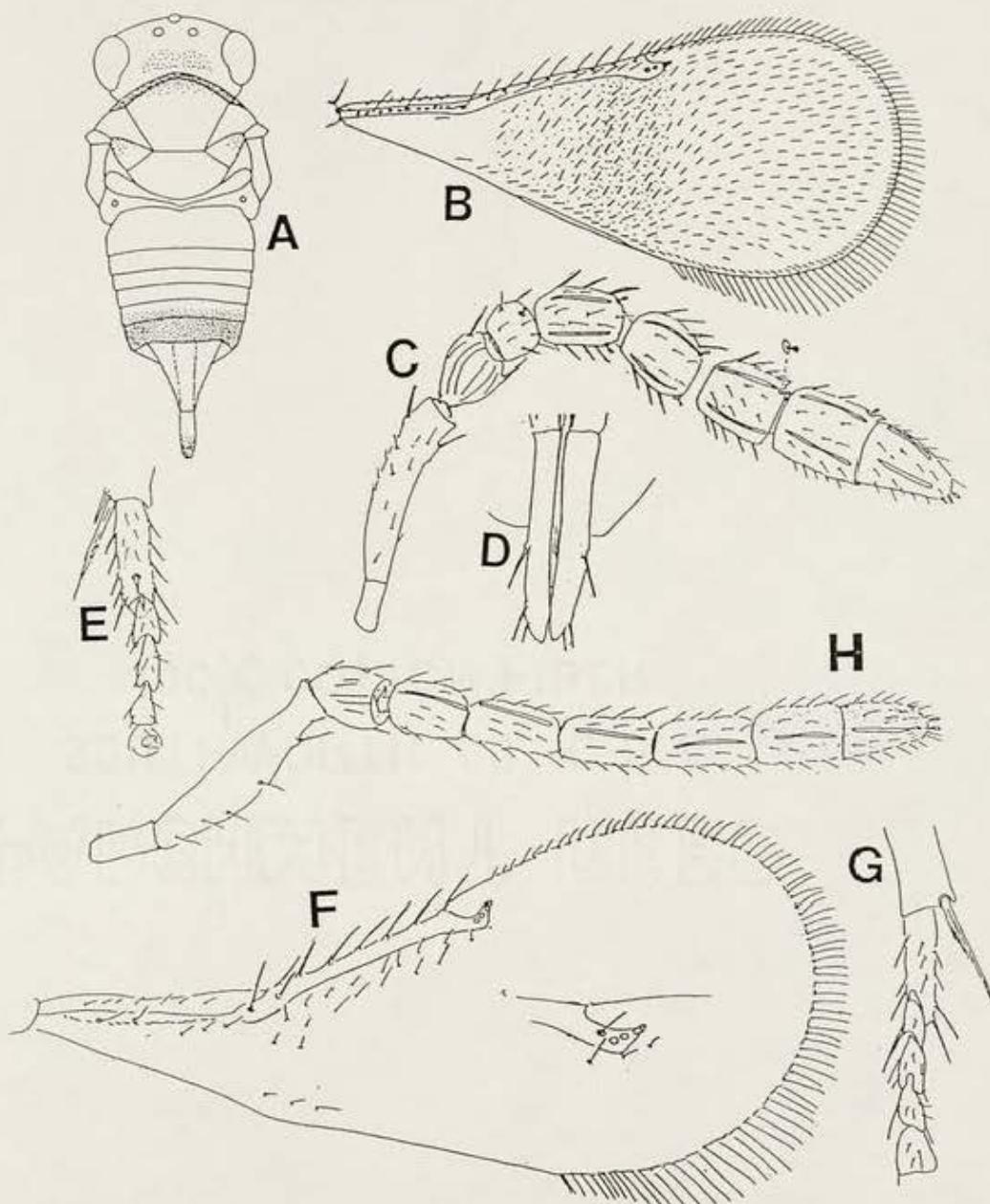


Figure 5.17. Female, *Encarsia brasiliensis* A) habitus B) forewing C) antenna
D) valvular III E) tarsus II. *catherinae* F) forewing G) tarsus II H) antenna.

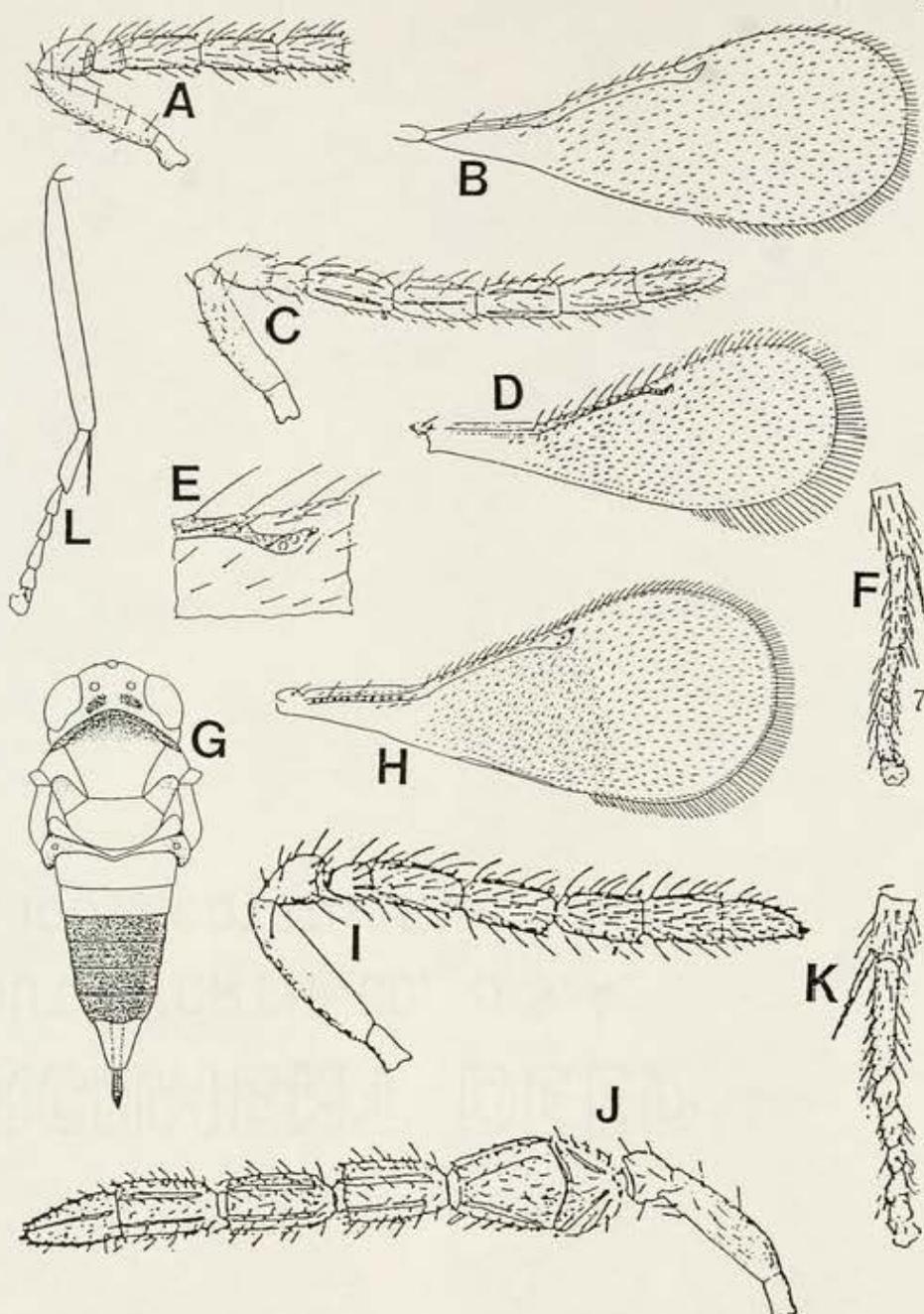


Figure 5.18. *Encarsia townsendi* A) ♀ antenna B) ♀ forewing, *divergens*
C) ♀ antenna D) ♀ forewing E) stigmal vein F) tarsus II, *opulenta*
G) ♀ habitus H) ♀ forewing I) ♀ antenna J) ♂ antenna K) tarsus II.

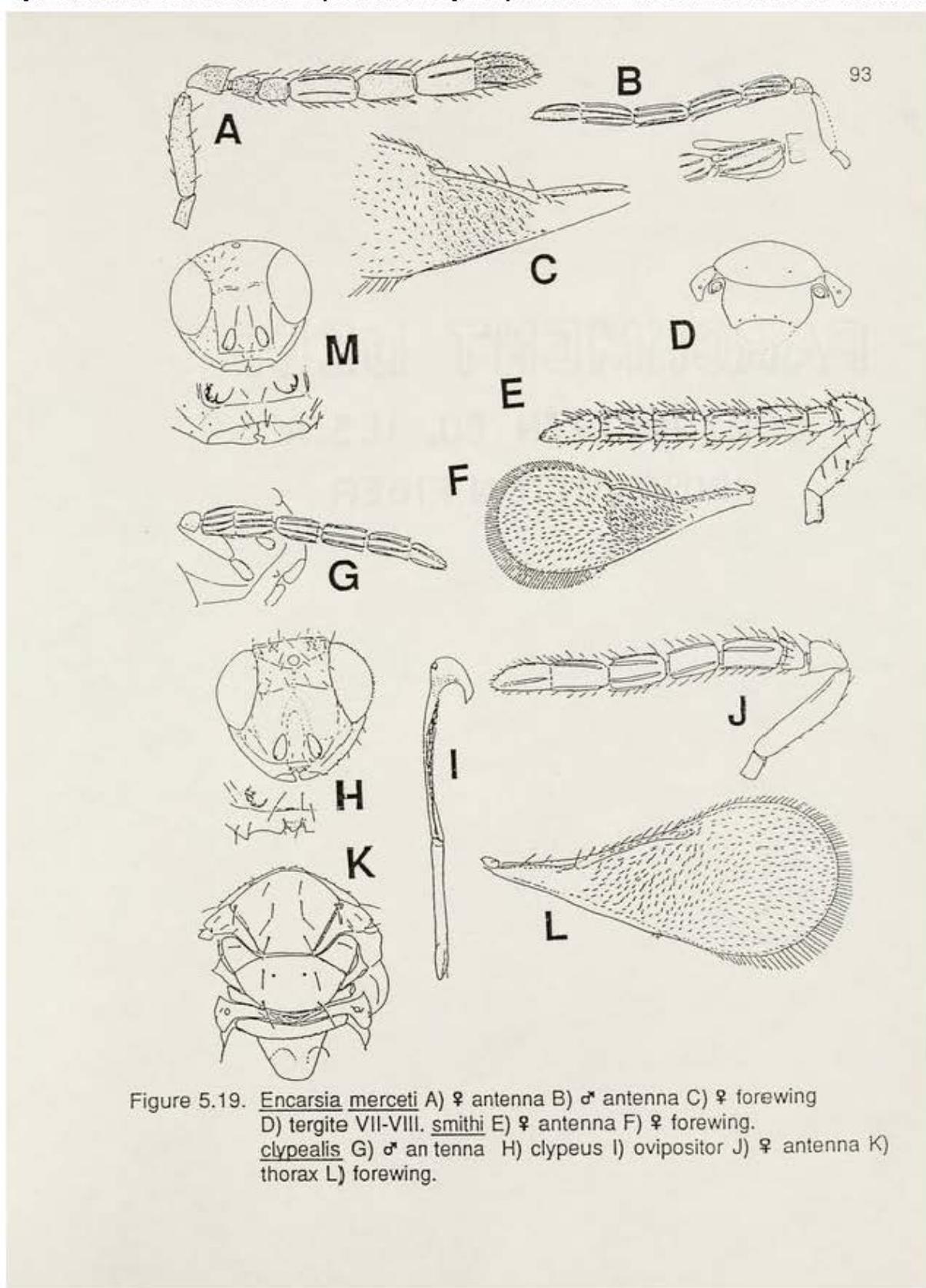


Figure 5.19. *Encarsia merceti* A) ♀ antenna B) ♂ antenna C) ♀ forewing
D) tergite VII-VIII. *smithi* E) ♀ antenna F) ♀ forewing.
clypealis G) ♂ antenna H) clypeus I) ovipositor J) ♀ antenna K)
thorax L) forewing.

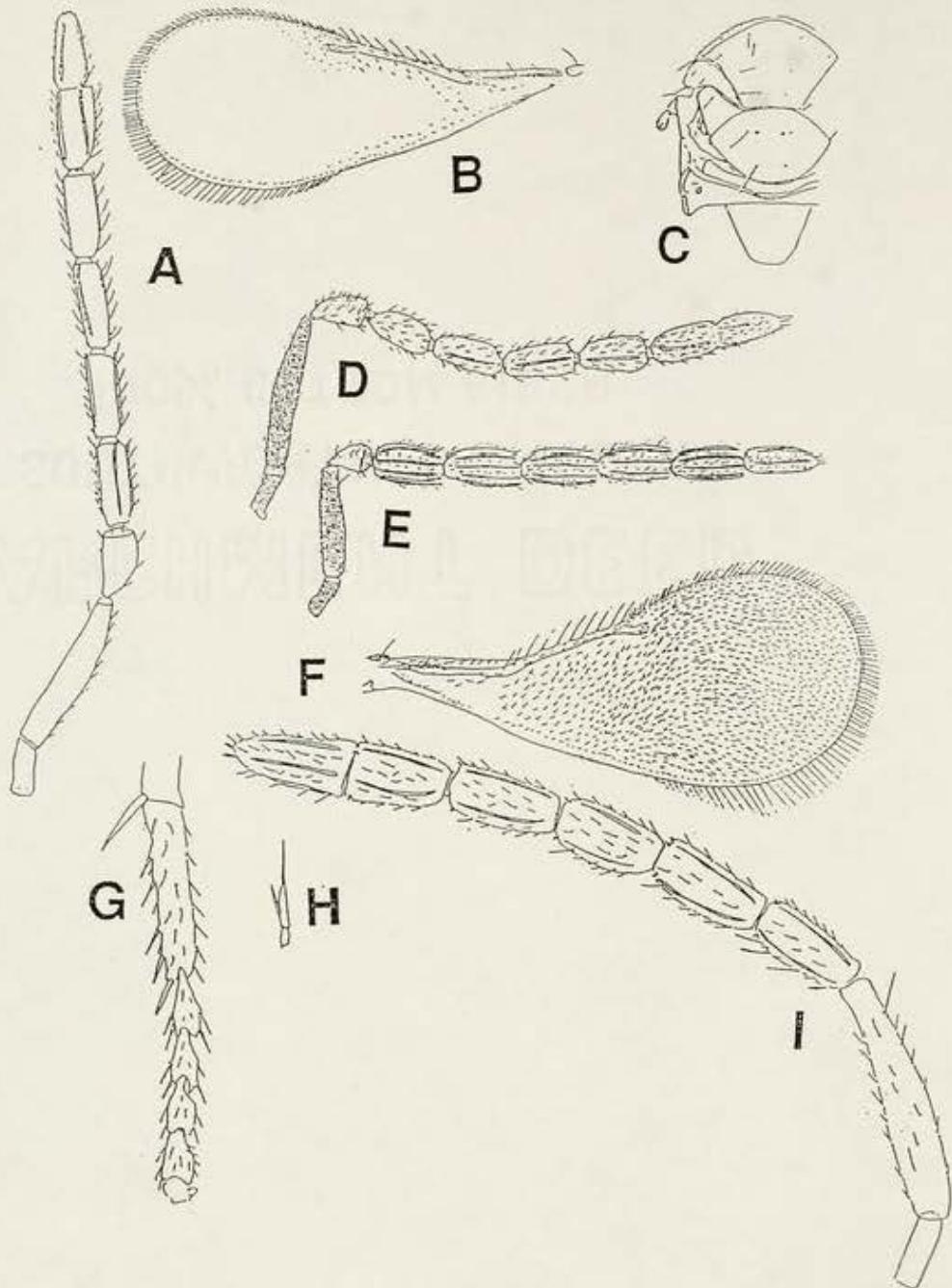


Figure 5.20. *Encarsia inaron* A) ♀ antenna B) forewing C) thorax.
lopezi D) ♀ antenna E) ♂ antenna F) forewing. *coquillettii*
G) tarsus II H) maxillary palp I) ♀ antenna.

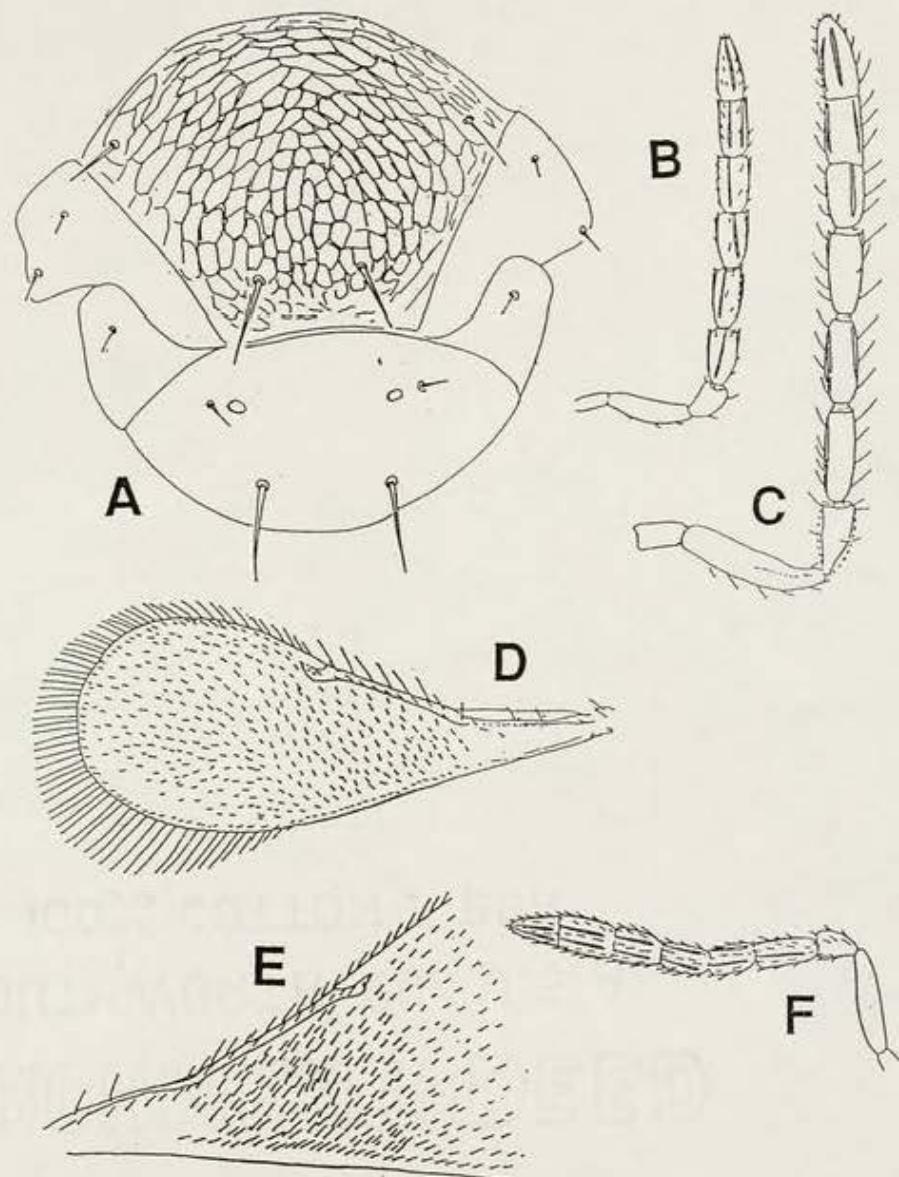


Figure 5.21. *Encarsia lahorensis* A) ♀ thorax B) ♂ antenna C) antenna
D) ♀ forewing. *ciliata* E) forewing E) ♀ antenna.

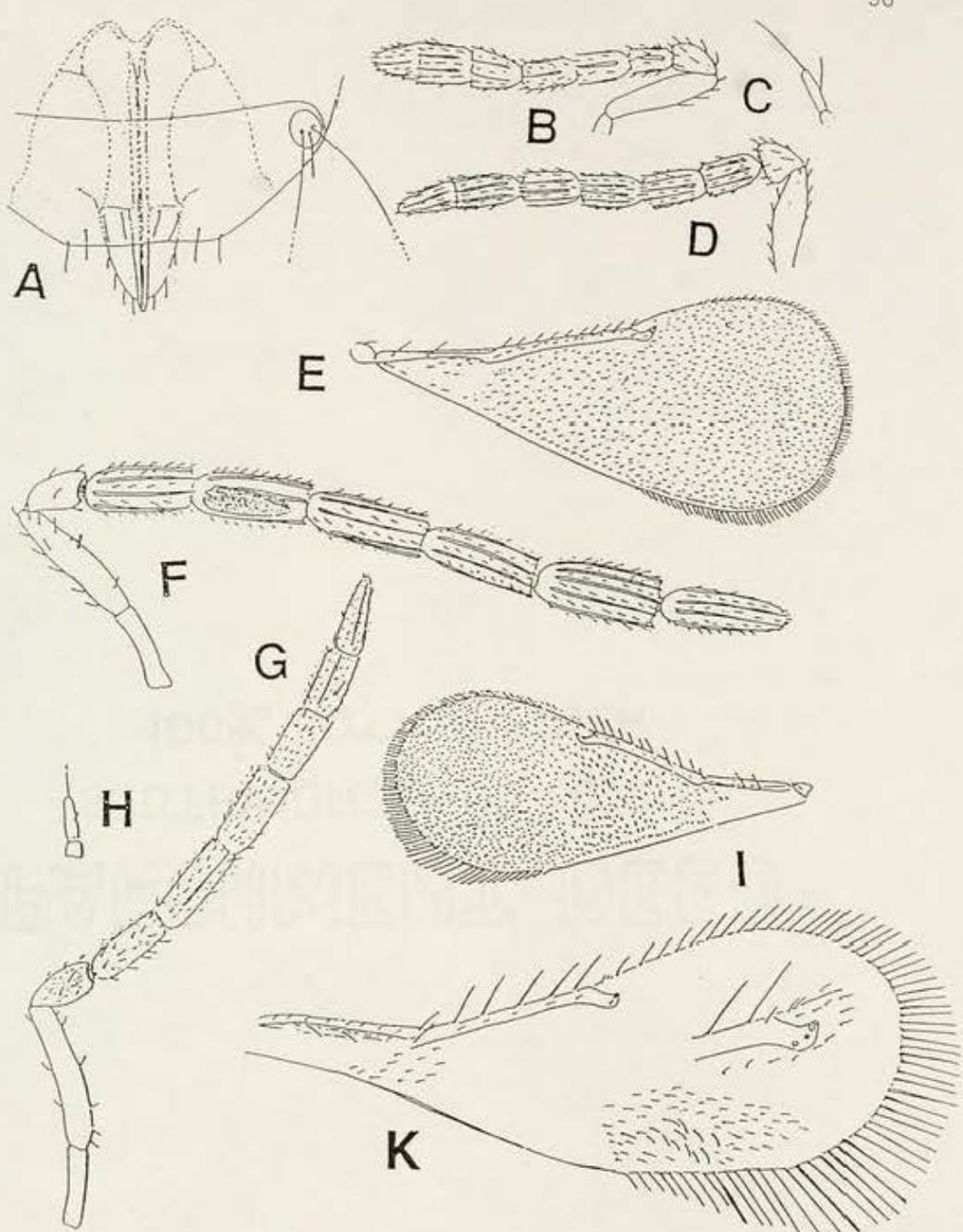


Figure 5.22. *Encarsia peltata* A) ovipositor B) ♀ antenna C) maxillary palp
D) ♂ antenna E) forewing. *plaumanni* F) ♂ antenna G) ♀ antenna
H) maxillary palp I) forewing.

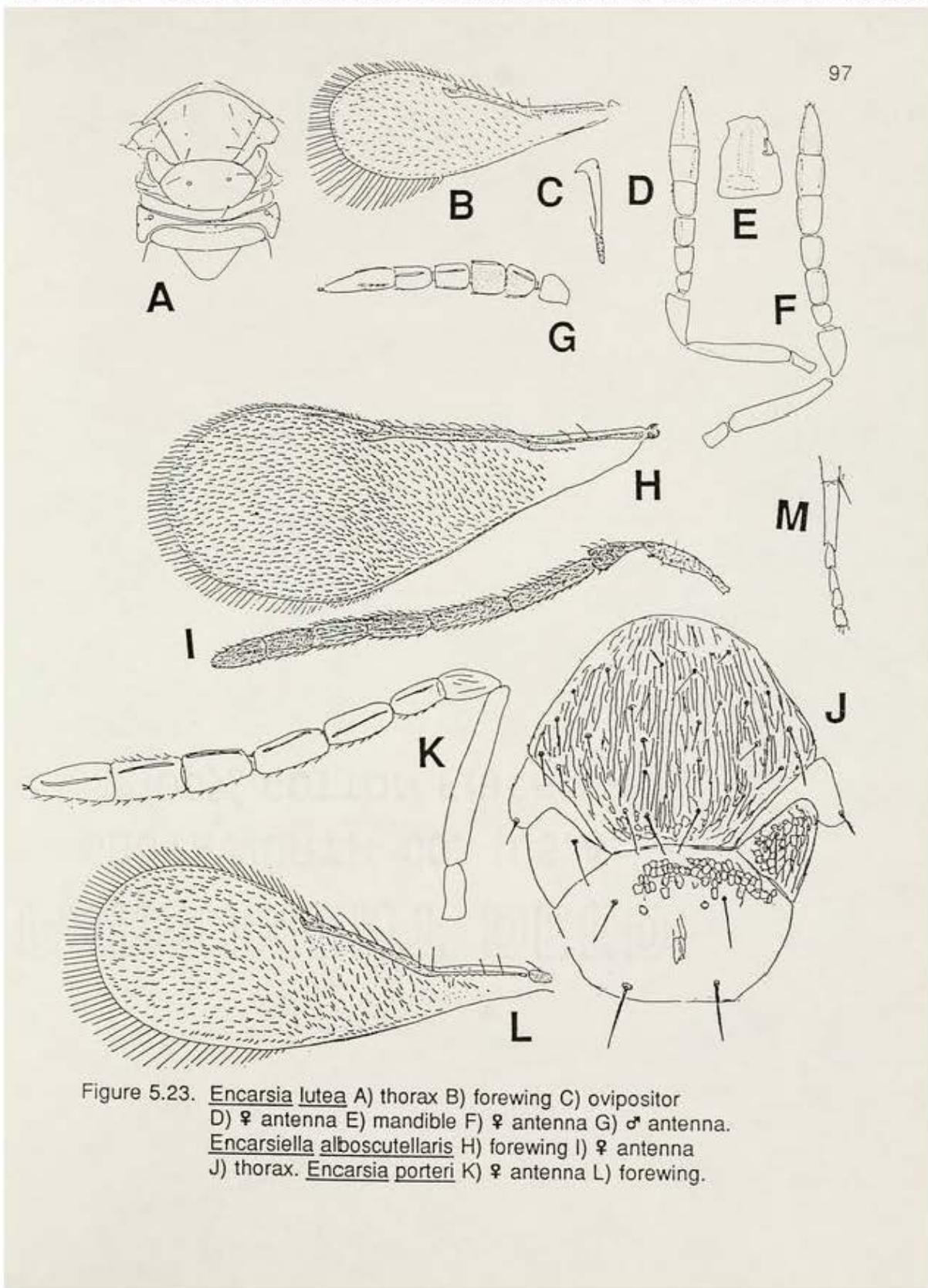


Figure 5.23. *Encarsia lutea* A) thorax B) forewing C) ovipositor
D) ♀ antenna E) mandible F) ♀ antenna G) ♂ antenna.
Encarsiella alboscutellaris H) forewing I) ♀ antenna
J) thorax. *Encarsia porteri* K) ♀ antenna L) forewing.

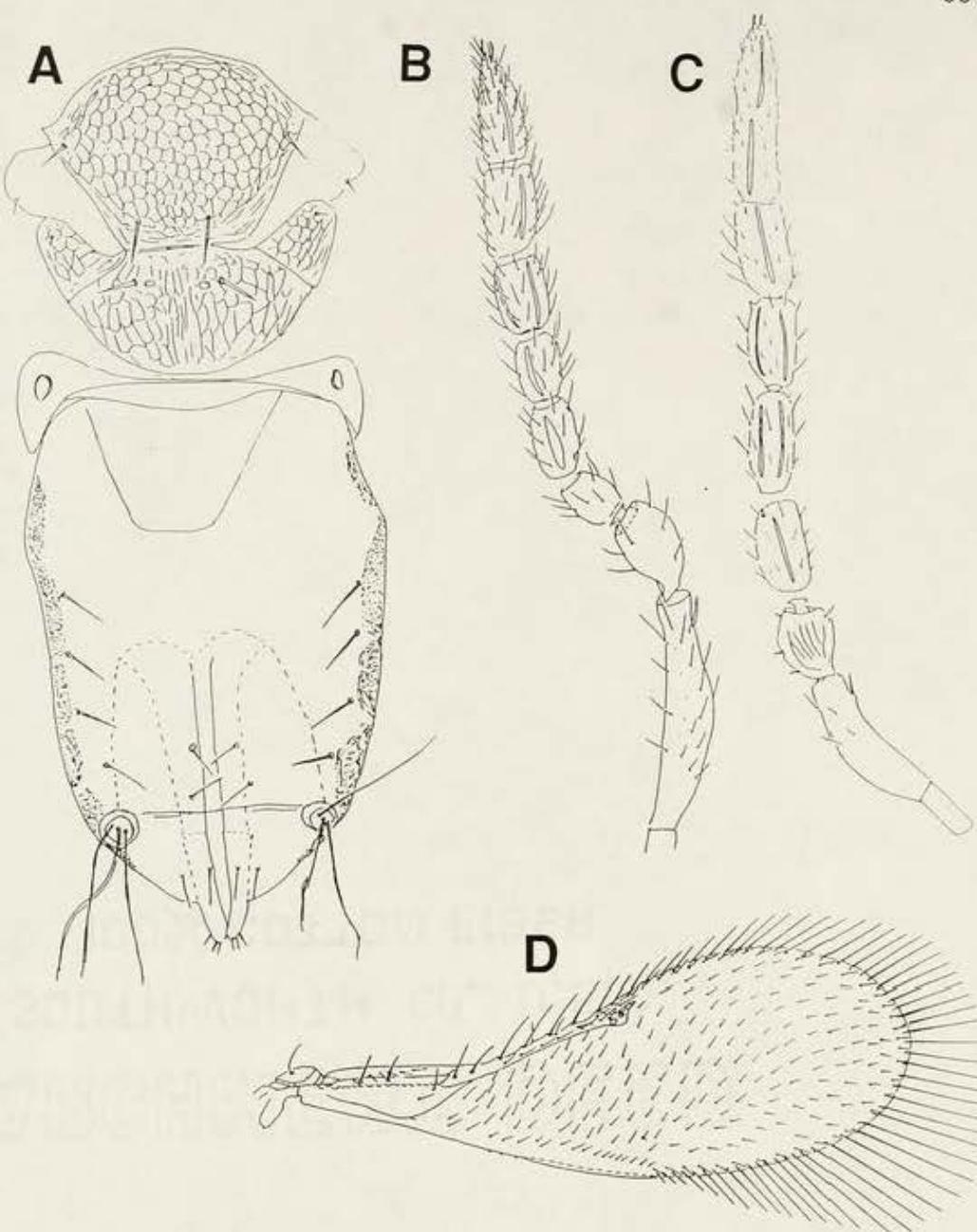


Figure 5.24. Encarsia polaszeki A) habitus B) forewing C) ♀ antenna D) ♂ antenna

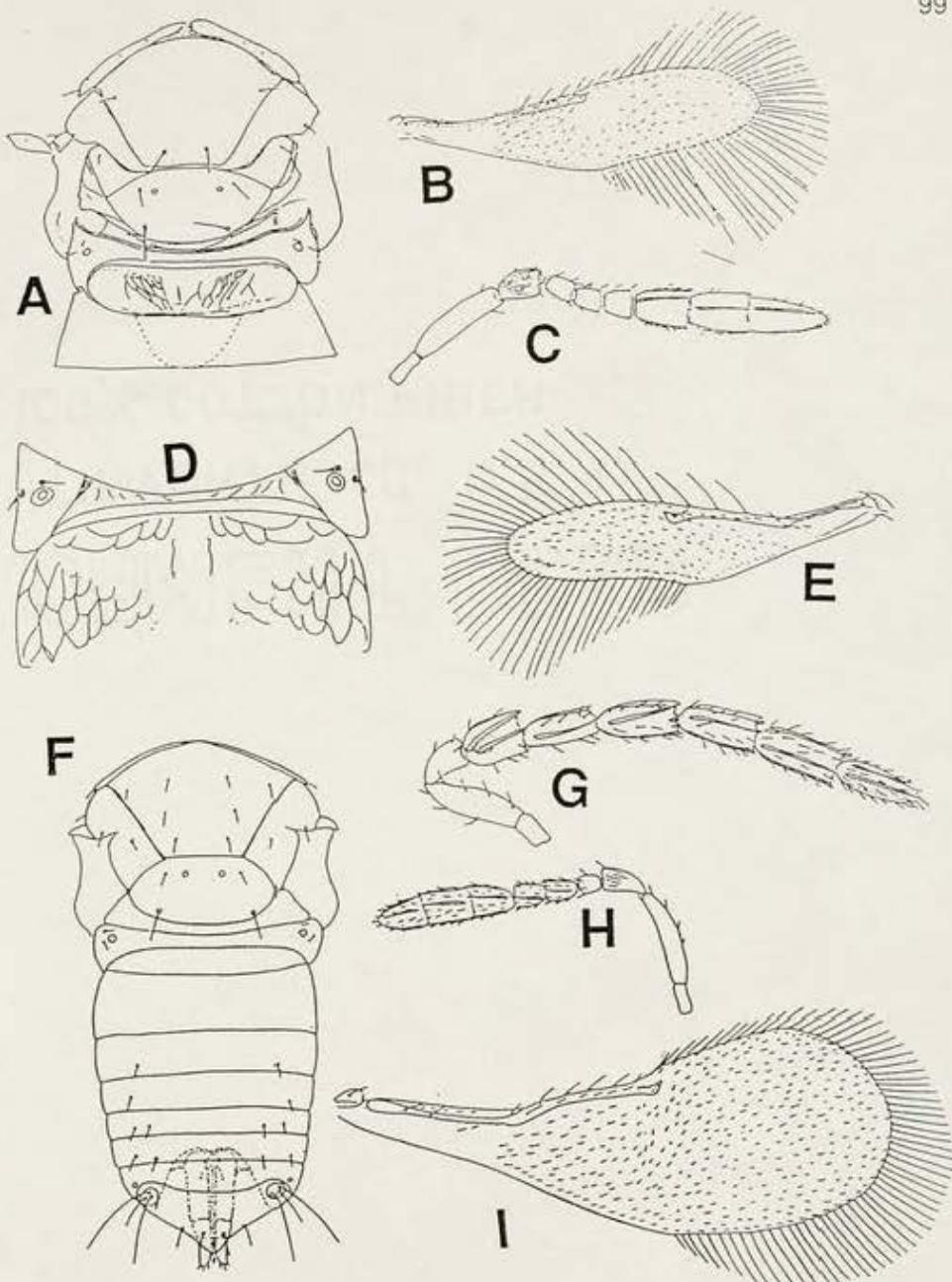


Figure 5.25. Female. *Encarsia citrina* A) thorax B) forewing C) antenna.
E. lilyngae D) petiole E) forewing G) ♀ antenna. *aurantii* F) habitus
H) ♀ antenna I) forewing.

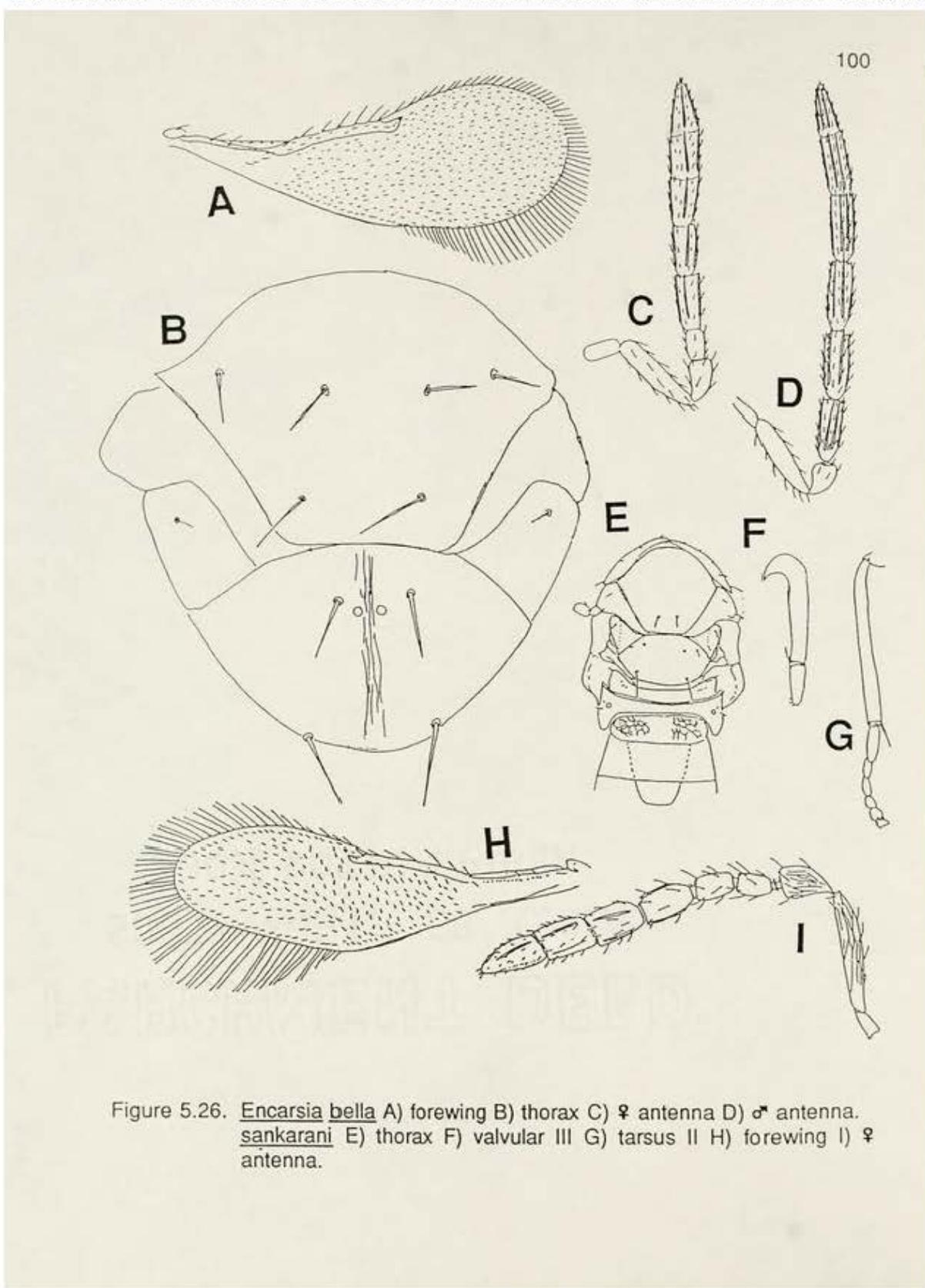


Figure 5.26. *Encarsia bella* A) forewing B) thorax C) ♀ antenna D) ♂ antenna.
sankarani E) thorax F) valvular III G) tarsus II H) forewing I) ♀ antenna.

CHAPTER 6

ENCARSIA SPECIES AND SPECIES GROUPS

6.1. Species Groups

Subgeneric classification of Encarsia species into groups based on well-defined characters, is often complicated by the large degree of interspecific and intraspecific variation that many species exhibit. Viggiani and Mazzone (1979) proposed fourteen Encarsia species groups based primarily on antennal and wing characters. Admittedly, they regarded these groups as only tentative in nature. Many of these species groups were not well defined, and there was some overlap and ambiguity as to which group many of the species were placed. Subsequently, Viggiani (1981;1988) in several publications has designated other species groups. Hayat (1989) outlined nineteen species groups and provided additional characters that could be used to separate species groups created by Viggiani and Mazzone (1979).

At present, it is not known which species groups should be considered monophyletic and which are paraphyletic taxa placed in the same group based on few shared (= synapomorphic) characters. For the purposes of identification, it is convenient to place species into groups that share a specific "stable" character.

For example, species that have the placoid sensillae on the scutellum in very close proximity to each other could be placed into the strenua group. Such a group would most likely be paraphyletic based solely on that character. E. bella and E. quercicola have the placoid sensillae close together but share more characters with species placed in the aurantii and opulenta groups, respectively, than they do with members of the strenua group. An alternative would be to place these species in their own species groups, based on several shared characters. I have made an effort to better define the criteria for placement of the species in each group and avoid the creation of paraphyletic species groups based on a single character or a few synapomorphies. Also, caution must be exercised not to evaluate the relatedness of one species group to another based on a single or very few characters. For example, the apomorphic character, heteronomous tarsi (4-segmented tarsi of leg II), has probably been derived independently in three separate lineages, and is found in the formosa, cubensis and singularis species groups. Based on a wide array of both morphological and biological characters, these groups appear more closely related to the pentamerous (all 5-segmented tarsi) species groups inaron, parvella and citrina, respectively, than they are to each other.

I have placed the following New World Encarsia species in the species groups given below. Extralimital species, those not known from the New World, are given in brackets. I did not have the opportunity to examine many of the extralimital species and have placed most of them in groups as they were

assigned by Hayat (1989). Species group placement should still be considered tentative until more is known of the genus on a worldwide basis and many characters are analyzed. I have proposed two new species groups, the Porteri and Plaumannii Groups; and three new subgroups of the Strenua Group: the strenua, quercicola and bella subgroups. Although most of these species groups consist of one or very few species and are only represented in the New World, further studies of the world fauna of Encarsia undoubtedly yield more species and a more extended range. Characterization of these and other species groups is given at the beginning of each species group section. The groups are not listed in any particular sequence, other than, listing the species groups whose members parasitize aleyrodids in the New World first, followed by the species groups which are parasitoids of diaspine scales or those that are not known to occur in the New World. A question mark is placed before the species in which there is some doubt as to which group they should be placed.

Species Groups

1. CUBENSIS GROUP: cubensis, nigriceps, quaintancei.
2. FORMOSA GROUP: brunnea, desantisi, formosa, gallardoi, guadeloupae,
haitiensis, luteola, meritoria, variegata.
3. PARVELLA GROUP: americana, basicincta, pergandiella, lanceolata spec.
nov., [acuadaleyrodes, aleuroplati, arabica?, aseta,
citrofila, gerlingi, longifasciata?, mineoi, nipponica,
parvella]. (longifasciata and arabaci? placed in the
longifasciata group, by Hayat 1989).

4. STRENUA GROUP:

4.1. Subgroup Strenua: armata, citrella, dialeurodes, pseudocitrella spec. nov, [(?) brevivena, lehri, longivalvula, macroptera, martima, mulyali, norani, perstrenua, primitiva].

4.2. Subgroup Quercicola: catherinae, lycopersici, portoricensis, quercicola.

4.3. Subgroup Bella: koebelei, bella.

5. OPULENTA GROUP: brasiliensis, clypealis, divergens, ? merceti, opulenta, ?smithi, townsendi, [albiscutellum, aleurotubae, bangalorensis, circumsulpturata, coimbatorensis, ishii, longicauda, nigrifemur, terebrator]. (merceti and bennetii placed by Hayat in the merceti group).

6. INARON GROUP: coquillettii, inaron, lopezi, longicornis [adrianae, aethiopica, azimi, galilea, gunturensis, persequens, reticulata, seminigriclava, siphonini, margaritiventris].

7. LUTEA GROUP: lutea, [abatei, agarwali, asterobemisiae, davidi, dialeuroporae, indica, marinikia, udaipuriensis].

8. LAHORENSIS GROUP: lahorensis, ciliata, [aleurochitonis, ? confusa].

9. PORTERI GROUP: porteri, polaszeki spec. nov.

10. PLAUMANNI GROUP: plaumannii.

11. AURANTII GROUP: aurantii, peltata, perniciosi, [aethiopica, affectata,
aleurotubae, amicula, bicolor, brimblecombei,
brittanica, circumsculpturata, gigas, intermedia,
olivina].
12. CITRINA GROUP: agilior, citrina, lounsburyi, [flavus, fulvus, latipennis,
? leucippi, pseudaonidiae].
13. INQUIRENDA GROUP: aspidicola, berlesei, diaspidicola, fasciata, peruviana,
sankarani, elongata, [nupta, paradiaspadicola,
explorata, inquirenda, inserens, insulana,
leucaspidis, tennysoni].
14. PERFLAVA GROUP: antiopa, cibcensis, dourunga, leptosoma,
leucippi, nigriventris, perflava, plana, pseudococci,
taciti, unfasciata].
15. ELEGANS GROUP: [bifasciafacies, elegans, isaaci, narayananai,
trivittata].
16. TRICOLOR GROUP: [flavoscutellum, gautieri, norani, shutovae, tricolor].
17. SINGULARIS GROUP: [africana, lilyingae, singularis].

6.2. Species and Species Group Diagnosis and Discussion

The following is a diagnosis of the New World Encarsia species groups,
and the described species of Encarsia that parasitize whiteflies in the New World,

including the description of three new species. Also, characteristics of species groups (not individual species) of Encarsia that are parasitoids of diaspine scale insects recorded from the New World are given. New host or distribution records are prefixed by an asterisk (*), and records on introduced species are given by (') following the locality. Specimen measurements are given in microns, accurate to the nearest 10 microns. Measurements given by other authors are followed by a superscript (a).

6.2.1. CUBENSIS GROUP

DIAGNOSIS: Tarsal formula 5-4-5; Forewing with rounded asetose area around stigmal vein. IDS:PSD ratio more than 2:1. F1 antennal segment shorter than pedicel. Club 3-segmented. Ovipositor short to moderate in length, never exceptionally extruded. Only known from aleyrodid hosts in the New World.

Males are known of two of the three described species in the cubensis group; both have antennal segments F5 and F6 fused and a unique round sensorial process on F2 segment. Species in this group are rather small, delicate bodied, and have few setae (2-4 pairs) on the mesoscutum. The cubensis group is most similar to the parvella group but differs by having a broader forewing, 4-segmented midtarsi and round sensorial processes on F2 segment of the male.

Encarsia cubensis Gahan

(Figures 5.6:a; 5.7:b,g)

Encarsia cubensis Gahan, 1931:121.Trichoporus cubensis (Gahan) in Dozier 1933:92.HOLOTYPE: ♀ reared from Aleurothrixus howardii (= A. floccosus),

Santiago de las Vegas, Cuba. In USNM (Type No. 43530) [Examined].

DIAGNOSIS: The female E. cubensis can be distinguished from other species of the cubensis group by its very short and quadrate F1 segment, dark abdomen and 2 pairs of mesoscutal setae.

FEMALE: 500^a µm. Head, pronotum, axillae, a broad transverse band across middle of gaster and its sides, blackish. Scutellum, propodeum, all legs and base of gaster, pale yellow; wings hyaline. Mesoscutum 1.2 times wider than long with broad uniform hexagonal areolae and 2 pairs (2ML;2MC) of stout setae. Scutellum 0.7 times mesoscutum length with elongate longitudinal sculpturing in the central region, becoming wider and broadly hexagonal laterally; ISD:PSD ratio 2.5:1. Axillae with elongate areolae, seta located apically. Gaster ovate, 1.2 times longer than thorax. Ovipositor moderate in length, arising at level of tergum IV and subequal to length of midtibia. Valvular III pale, narrow and elongate about 3 times longer than wide and about 0.4 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: 1.7, 4.7, 2.0, 1.0, 2.0, 1.8, 2.0, 2.2, 2.5; length/width ratios 3.00, 5.00, 1.82, 1.00, 1.82, 1.64, 1.82, 1.83, 2.27. Club 3-segmented, linear sensillae present on F2-6. Forewing with asetose area under

stigmal vein and 3 basal setae. Discal cell almond-shaped, about 1.2 times longer than disk width. Fringe long, about 0.4 times as long as disk width. Marginal vein 1.2 longer than submarginal vein. Midtibial spur 0.8 times as long as length of corresponding basitarsus. Tarsal formula 5-4-5.

Male: Unknown.

HOSTS: Aleurothrixus floccosus (Maskell) on Spondias mombin, Catalpa longissima, and Guajacum officinale.

DISTRIBUTION: * BRAZIL; CUBA; HAITI; * PUERTO RICO

NOTE: This species is rarely collected. Males are not known.

Encarsia nigricephala Dozier

(Figures 5.6:b; 5.7:c,d,h)

Encarsia nigricephala Dozier, 1937:129.

HOLOTYPE: ♀ reared from Bemisia sp. on Euphorbia hypericifolia, Feb. 26, 1936, by H. L. Dozier, Mayaguez, Puerto Rico. In USNM (No. 51607) [Examined].

DIAGNOSIS: The female of E. nigricephala can be distinguished from species in the cubensis group by its dark brown head and anterior 0.33-0.66 of mesoscutum, contrasting with the pale posterior portion of mesoscutum, scutellum and gaster. It has 2 pairs of mesoscutal setae.

FEMALE: 460^a µm. Head, pronotum, and anterior 0.33-0.66 of mesoscutum dark brown and posterior portion of mesoscutum, axillae, scutellum,

gaster and legs pale yellow; wings hyaline. Mesoscutum 1.9 times wider than long with broad uniform hexagonal areole and with 2 pairs (2ML;2MC) of stout setae. Scutellum 0.8 times as long as mesoscutum with elongate longitudinal sculpturing in the central region, becoming wider and broadly hexagonal laterally; ISD:PSD ratio to 3:1. Axillae areolae elongate with setae located apically. Gaster ovate, 1.6 times longer than thorax. Ovipositor moderate in length, arising at level of tergum IV and 0.9 times as long as midtibia. Valvula III pale and 4 times longer than wide and about 0.4 times length of the ovipositor. Antennal segments R-F6 in the following ratios to F1: 1.1, 2.8, 1.1, 1.0, 1.2, 1.1, 1.1, 1.2, 1.5; length/width ratios 3.4, 5.6, 1.5, 2.0, 2.38, 2.0, 1.84, 1.73, 2.27. Club 3-segmented, linear sensillae present on F2-6. Forewing with asetose area under the stigmal vein and 3 basal setae. Discal cell almond-shaped, about 1.4 times longer than forewing width. Fringe long, about 0.5 times the forewing width. Marginal vein 1.2 times longer than submarginal vein. Midtibial spur 0.8 times as long as basitarsus II. Tarsal formula 5-4-5.

MALE: Head, pronotum, mesoscutum (except for paler lateral margins), axillae and gaster, dark brown. Scutellum and legs pale. Wings hyaline. Antennal segments with the following ratios to F1: 1.3, 3.0, 1.0, 1.0, 2.0, 1.3, 1.4, 3.2, F5 and F6 fused, F2 longer than F3 and with 2 large, round sensorial processes. Ventral margins of funicle segments F2 and F3 longer than dorsal margins. Thoracic sculpturing and setation and forewing characteristics similar to those of female.

HOSTS: *Bemisia tabaci*, * *Trialeurodes abutiloneus*, *T. floridensis*, *T. vaporiorarum*.

DISTRIBUTION: USA: FL, GA, TX; BARBADOS; BRAZIL; COLOMBIA; GRENADA; GUADELOUPE; HONDURAS; JAMAICA; MEXICO; PUERTO RICO; REUNION; VENEZUELA.

NOTE: *E. nigriccephala* shows little intraspecific variation. Very few specimens have the dark mesoscutal spot extending almost to the posterior margin of the mesoscutum. It is one of three major SPWF parasitoids in Florida and many Caribbean and Latin American countries.

Encarsia quaintancei Howard

(Figures 5.6:c; 5.7:a,e,f,i)

Encarsia quaintancei Howard 1907:79.

Prospaltella perspicuipennis Girault, 1910:234. Synonomy by Polaszek et al. 1992:387.

Encarsia perspicuipennis (Girault): Viggiani, 1986:71 new combination.

HOLOTYPE: ♀ reared from Aleyrodes sp. on Polygonum sp., Aug. 29, 1900, Bladensburg Rd, Washington, D.C by Theo Pergande. In USNM (Type No. 10304) [Examined].

DIAGNOSIS: The female of *E. quaintancei* can be distinguished from other species in the cubensis group by its bright yellow scutellum and dark abdomen, cylindrical F1 segment, and 3-4 pairs of mesoscutal setae.

FEMALE: 660 μm . Head, pronotum, axillae and gaster, dark brown.

Scutellum and all legs lemon yellow; wings hyaline. Mesoscutum 1.3 times wider than long with elongate hexagonal areolae and 3-4 pairs (2ML;2MC;2me2,3) of stout setae (secondary setae along the outer margins, not central). Scutellum 0.8 times as long as mesoscutum with elongate longitudinal sculpturing in central region, becoming wider and broadly hexagonal laterally; ISD:PSD ratio 4.0:1. Axillae areolae elongate with setae located apically. Gaster 1.6 times as long as thorax. Ovipositor moderate in length, equal to or slightly longer than midtibia, arising at level of tergite IV. Valvular III pale, narrow, elongate about 2.8 times as long as wide and about 0.4 times the as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: 1.5, 4.2, 1.7, 1.0, 1.3, 1.8, 1.7, 1.7, 2.3; length/width ratios: 3.0, 6.0, 1.88, 1.25, 1.63, 2.22, 1.9, 1.7, 2.44. Club 3-segmented, linear sensillae present on F3-6; long basiconic setae on apex of F 1-4. Forewing with asetose area under the stigmal vein, 2 basal setae. Discal cell rounded apically, 1.3 times longer than disk width. Fringe long, about 0.4 times as long as disk width. Marginal vein 1.3 times longer than submarginal vein. Midtibial spur 0.7 times as long as basitarsus II. Tarsal formula 5-4-5.

MALE: Head, pronotum, mesoscutum axillae and gaster dark brown.

Scutellum and legs pale; wings hyaline. Antennal segments with following ratios to F1: 1.3, 3.0, 1.2, 1.0, 1.2, 1.8, 1.8, 3.8 (F5-F6 fused). F3 longer than F2 and with 2 large, round sensorial processes. Thoracic sculpturing and setation and forewing characteristics similar to those of female. E. quaintancei males are very

similar to *E. nigriceps* males but may be distinguished by the F3 being longer than F2 segment and by having 3-4 pairs of mesoscutal setae.

HOSTS: *Aleurothrixus floccosus*, *Aleyrodes* sp., *Bemisia tabaci*, *Trialeurodes abutiloneus*, * *T. packardi*, *Trialeurodes* sp.

DISTRIBUTION: USA: DC, FL, IL; GUADELOUPE; JAMAICA; MEXICO; PUERTO RICO; VENEZUELA.

BIOLOGY: Dysart (1966) reported that this species completed its life cycle on *Trialeurodes abutiloneus* in 10 to 25 days, overwintered in the whitefly pupae and darkened the puparia of its whitefly host. The figure of the male antennae in Dysart's publication is in error, it shows F5 and F6 separated and F2 segment without the round sensorial process.

NOTE: This species is reared sporadically in Florida. Large numbers of individuals emerge in the spring. During the remainder of the year, they are only occasionally reared. The validity of genus *Aleyrodes* as the host from which this whitefly was described is suspect. Many whitefly species that were once placed in the genus *Aleyrodes*, have since been placed in other genera. There are no species of *Aleyrodes* recorded east the Mississippi River, except those listed as hosts for several parasitoids that were described at the turn of the century. Based on the host plant and the geographic area it was found, I suspect that the host was probably a species of *Trialeurodes*.

6.2.2. FORMOSA GROUP

DIAGNOSIS: Tarsal formula 5-4-5. Forewing uniformly setose. ISD:PSD

ratio greater than 2:1. Club usually 2-segmented. Ovipositor moderate in length, subequal to midtibia and not exceptionally extruded. Parasitoids of aleyrodids in the New World.

With few exceptions, species of the formosa group have at least 4 pairs (usually more) of mesoscutal setae with often very conspicuous sculpturing consisting of numerous hexagonal areolae with well-defined margins. The legs and antennae are elongate; the funicle segments are usually at least 1.5 times longer than wide. Species in this group have only been recorded from aleyrodid hosts in the New World. E. formosa, a New World species, has been introduced into many countries throughout the world for the control of the greenhouse whitefly, Trialeurodes vaporiorarum. Recently, several specimens of E. guadeloupae, were reared by Dr. F. D. Bennett from collections made in Thailand. Many species belonging to this group appear to be most closely related to members of the inaron group based on their elongate antennal segments, dark thorax and pale abdomen coloration, and setation and sculpturing of the mesoscutum and scutellum. They differ primarily by having 4-segmented tarsi on leg II.

Encarsia brunnea (Howard)

(Figures 5.8:a,b)

Prospaltella brunnea Howard, 1908:234.

Encarsia brunnea Howard, in Viggiani 1987:135.

HOLOTYPE: ♀ reared from Aleyrodes sp. (undescribed) on a climbing

vine, Bayamon, Puerto Rico, Jan. 1899 by A. Busck. In USNM (Type No. 12165).

DIAGNOSIS: The female of E. brunnea can be distinguished from other species of the formosa group by possessing the following combination of characters: dark gaster, 3-segmented club, very short marginal vein (about half the length of the discal cell) and only 4 pairs of mesoscutal setae.

FEMALE: 850^a µm. Body dark brown with thorax somewhat lighter. Center of the gaster occupied by a large white spot; wings hyaline. Mesoscutum with 4 pairs of setae. Ovipositor as long as midtibia. Antennal segments R-F6 in following ratios to F1: 0.86, 2.86, 1.14, 1.0, 1.14, 1.29, 1.29, 1.29, 1.57 and length/width ratios of: 3.0, 6.6, 1.6, 1.75, 2.0, 1.28, 1.28, 1.28, 1.57. Club distinctly 3-segmented, linear sensillae present on all funicle segments. Forewing uniformly setose. Discal cell rounded apically, 1.3 times longer than disk width. Fringe very short, about 0.10 times as long as disk width. Marginal vein very short, about half discal cell length and 0.88 times as long as submarginal vein. 2 basal setae. Midtibial spur 0.7 times as long as basitarsus II. Tarsal formula 5-4-5.

MALE: Unknown.

HOSTS: Aleyrodes sp. on climbing vine

DISTRIBUTION: PUERTO RICO.

NOTE: The identity of the host whitefly as being a species of Aleyrodes is suspect. (See discussion of E. quaintancei).

Encarsia desantisi Viggiani

(Figures 5.8:c,d,e)

Encarsia desantisi Viggiani 1985:82. Replacement name for bicolor DeSantis.Encarsia bicolor De Santis 1948:256. Preoccupied by bicolor Timberlake, 1926.Encarsia bicolor De Santis 1981:38 [description of ♂].

HOLOTYPE: ♀ [no data]. In UNLP [PARATYPE ♀ EXAMINED].

DIAGNOSIS: The female of E. desantisi can be distinguished from other species of the formosa group by possessing the following combination of characters: brown thorax and pale gaster with dark brown transverse bands on tergites V and VI. Midtibial spur very elongate, about equal to basitarsus II.

FEMALE: 660^a µm. Head, pronotum, center portion of mesoscutum, scutellum, axillae, metanotum, propodeum and hind coxae, brown. Legs and gaster pale with dark brown transverse bands on tergites V and VI. Wings hyaline, slightly infuscated at the base. Mesoscutum 1.3 times wider than long with elongate hexagonal areolae, and 4 pairs of stout setae (2ML;2mc1,2,3+2MC;2md1). Scutellum 0.7 times as long as mesoscutum with narrow longitudinal sculpturing between placoid sensillae, becoming wider and broadly hexagonal laterally; ISD:PSD ratio 7:1, Sc 2 setae very long about as long as scutellum. Axillae with elongate areolae and seta located apically. Gaster somewhat elongate, 2.1 times length of thorax. Ovipositor moderate in length, arising at level of tergum III and 1.2 times length of midtibia. Valvular III pale, 2.8 times longer than wide and about 0.4 times as long as ovipositor. Antennal segments R-F6 in the following ratios to

F1: 0.83, 3.17, 1.33, 1.0, 1.08, 1.33, 1.42, 1.66, 1.75, length/width ratios: 2.5, 7.6, 2.0, 1.71, 1.86, 2.28, 2.13, 2.50, 2.63. Club 2-segmented, linear sensillae present on F 2-6. Forewing uniformly setose. Discal cell rounded apically 1.1 times longer than disk width. Fringe long, about 0.35 times as long as disk width. Marginal vein 1.2 times longer than submarginal vein, 5-6 basal setae. Midtibial spur robust about 0.77-0.85 times as long as basitarsus II. Tarsal formula 5-4-5.

MALE: Body dark brown with pale legs and hyaline wings. All funicle segments subequal in length and about 2.3 times longer than wide. F5 and F6 partially fused. Thoracic sculpturing and setation and forewing characteristics similar to female.

HOSTS: Bemisia tabaci, * Trialeurodes vaporiorarum.

DISTRIBUTION: ARGENTINA; BRAZIL; * VENEZUELA.

Encarsia formosa Gahan

(Figures 5.8:f,g,h)

Encarsia formosa Gahan, 1924:14.

HOLOTYPE: ♀ reared from Trialeurodes vaporiorarum (Westwood) on Geranium sp., Twin Falls, Idaho. In USNM (Type No. 26180) [Examined].

BIOLOGY: Gerling 1960a, Lenteren et al. 1987.

DIAGNOSIS: The female of E. formosa can be distinguished from other species of the formosa group by possessing the following combination of characters: black head and thorax and pale gaster.

Midtibial spur short about 0.5 times as long as basitarsus II. Uniparental, males

rarely produced.

FEMALE: 600^a µm. Occiput very dark orange or brownish. Basal portion head, pronotum, axillae, scutellum and hind coxae, dark brown. Central and medial region of mesoscutum with large, dark brown triangular spot and lateral region light brown. Gaster, legs and antennae pale yellow; wings hyaline. Mesoscutum 1.7 times wider than long with elongate hexagonal areolae and 8-10 pairs of stout setae (2ML;2mc1,2,3,4+2MC;2me1,3). Scutellum 1.4 times as long as mesoscutum, with several rows of narrow longitudinal cells between placoid sensillae becoming wider and broadly hexagonal laterally; ISD:PSD ratio 6:1. Axillae tall with numerous small areolae, setae located apically. Gaster somewhat elongate, 1.4 times as long as thorax. Ovipositor moderate in length, arising at the level of tergum III and 0.9 times as long as midtibia, slightly extruded. Valvula III pale, narrow, about 0.37 times length of ovipositor. Antennal segments R-F6 in the following ratios to F1: 0.6, 2.4, 0.8, 1.0, 1.1, 1.2, 1.2, 1.2, 1.2, 1.2; length/width ratios: 3.0, 5.5, 1.7, 1.5, 2.3, 2.4, 2.4, 2.4, 2.5 (see discussion). Club 2-segmented, linear sensillae present on F 2-6; forewing uniformly setose. Discal cell rounded apically and as long as disk width. Fringe about 0.2 times as long as disk width. Marginal vein elongate, 1.5 times longer than submarginal vein. Basal group 5-6 setae. Midtibial spur short, about 0.5 times as long as basitarsus II. Tarsal formula 5-4-5.

MALE: Head, thorax and gaster dark brown; wings hyaline. Funicle segments subequal in length, very elongate, about 2.4 times longer than wide. F5

and F6 separated, not fused. Thoracic sculpturing and setation and forewing characteristics similar to female.

HOSTS: Aleuroglandulus malangae, Aleurotrachelus trachoides, Aleyrodes spiraeoides, A. lonicerae, A. proletella, A. spiraeoides, Bemisia tabaci, * Crenidorsum sp., Dialeurodes chittendeni, D. citri, * Tetraleurodes mori, * Trialeurodes abutiloneus, T. vaporiarum, * T. variabilis.

DISTRIBUTION: USA (widespread); COLOMBIA; COSTA RICA; ITALYⁱ; JAMAICA; MEXICO; PUERTO RICO; VENEZUELA; CHINA. New World origin, introduced into many countries throughout the world as a natural enemy of Trialeurodes vaporariorum.

NOTE: Host-induced morphological variation was observed in individuals of E. formosa. The body and appendages are more elongate and areolae of the mesoscutum and axillae smaller and more numerous on individuals reared from T. vaporiarum than on those reared from B. tabaci; the scape measured about 5.5 times longer than wide in the former versus 4.9 in the latter. E. formosa was seldom reared from field collections of B. tabaci. It has served as an effective biological control agent against the greenhouse whitefly, Trialeurodes vaporariorum, in many countries throughout the world.

Encarsia formosa when given a choice between parasitizing Bemisia tabaci or Trialeurodes vaporariorum, accepts B. tabaci less often (25%) than T. vaporariorum. Adults reared from B. tabaci are smaller, have fewer ovarioles, shorter lifespans, walk slower and thus parasitize fewer whiteflies than those reared from T. vaporariorum (van Lenteren 1990).

Encarsia gallardoi MarelliEncarsia gallardoi Marelli 1933:3.

HOLOTYPE: ♀ ex. aleyrodid on Citrus sp., Buenos Aires, Argentina, 27 XII 1929, J. A. Costa collector. In UNLP.

DIAGNOSIS: E. gallardoi is indistinguishable from E. meritoria Gahan based on Marelli's description and figures. I refrain from placing E. gallardoi in synonymy with E. meritoria until I have the opportunity to examine the holotype specimen of E. gallardoi.

FEMALE: 705^a µm. Eyes black with red margins. Antennae dusky. Mesoscutum, scutellum, axillae, legs and gaster, yellowish. Base of gaster slightly darker; wings hyaline. Mesoscutum with irregular pentagonal areolae and 6 pairs of setae, central area with narrow longitudinal reticulations becoming broadly hexagonal laterally. Gaster short, 1.2 times longer than thorax. Antennal segments R-F6 in the following ratios to F1: 1.0, 2.72, 1.0, 1.0, 1.39, 1.44, 1.55, 1.50, 1.55. Club 2-segmented. Forewing length and maximum width 737 and 297.5, respectively. Marginal vein slightly longer than submarginal vein. Midtibial spur elongate about as long as basitarsus II. Tarsal formula 5-5-5.

MALE: Unknown.

HOST: Aleurodicus juleikae.

DISTRIBUTION: ARGENTINA.

NOTE: I was unable to examine type specimens of E. gallardoi. The specimen loaned to me by the USNM, identified as E. gallardoi by A. Gahan, was virtually identical to E. meritoria specimens

Encarsia guadeloupae Viggiani

(Figures 5.9:a,b,c,d,e)

Encarsia guadeloupae Viggiani, 1987:125.

HOLOTYPE: ♀ ex. Aleyrodes sp. on Persea americana, Wonche, Guadeloupe, 12 VI 1985 by J. Etienne. In UNP [Reference specimens compared with holotype specimen by G. Viggiani].

DIAGNOSIS: The female of E. guadeloupae can be distinguished from species of the formosa group by the following combination of characters: blackish head, thorax and gaster; 2-segmented club; numerous pairs (9) of mesoscutal setae; and elongate marginal vein about as long as discal cell.

FEMALE: 600^a µm. Head, pronotum, mesoscutum, axillae and gaster, blackish. Legs and antennae pale except for brownish hind coxae, radical, scape, F5 and F6 segments; wings hyaline. Mesoscutum 1.6 times wider than long with numerous, slightly elongate hexagonal areolae and 9 pairs of long and stout setae (2ML;2mc_{1,2,3,4}+2MC;2me_{1,2};2mf₁). MC setae exceptionally long, reaching beyond base of Sc 1 setae. Scutellum 0.75 times as long as mesoscutum with several rows of short and narrow longitudinal cells between the placoid sensillae, becoming slightly wider and broader laterally; ISD:PSD ratio 7:1. Axillae with numerous small areolae, setae short and located apically. Gaster ovate, 1.3 times as long as thorax. Ovipositor moderate in length, arising at level of tergum I and 1.2 times as long as midtibia. Valvular III pale, 2.7 times longer than wide and about 0.41 times as long as ovipositor. Antennal segments R-F6 in the following

ratios to F1: 0.66, 2.39, 1.05, 1.0, 1.11, 1.17, 1.17, 1.22, 1.33; length/width ratios: 2.4, 4.78, 1.90, 2.00, 2.22, 2.33, 2.2, 2.44, 2.66. Club 2-segmented, linear sensillae present on all funicle segments. Forewing uniformly setose. Discal cell rounded apically, 0.94 longer than disk width. Fringe short, about 0.2 times as long as disk width. Marginal vein elongate 1.25 times longer than submarginal vein. Basal group consisting of 3-4 setae. Midtibial spur about 0.75 times as long as basitarsus II. Tarsal formula 5-4-5.

MALE: Unknown.

HOSTS: Aleyrodes sp.

DISTRIBUTION: GUADELOUPE; * THAILAND.

Encarsia haitiensis Dozier

(Figures 5.8:1)

Encarsia haitiensis Dozier, 1932:118.

Trichoporus haitiensis (Dozier), in Dozier, 1933:92.

HOLOTYPE: ♀ reared from Aleurothrixus floccosus (Maskell) on Spondias mombin, Damien, Haiti, by ? H.L. Dozier. In USNM [Examined].

BIOLOGY: Kushishiro et al. 1983.

DIAGNOSIS: The female of E. haitiensis can be distinguished from most species of the formosa group by its entirely yellow body. It is most similar to E. meritoria but may be distinguished by its very short F1 segment that is only about 0.5 times as long as the F2 segment, and by its fuscous hind femur and petiole.

The scutellum is slightly longer (more round) than in E. meritaria.

FEMALE: 530^a µm. Body yellow, with pronotum and mesoscutum slightly darker. Antennae and legs pale. Hindfemur and tip of ovipositor fuscous. Wings hyaline. Mesoscutum 1.5 times wider than long with numerous small hexagonal areolae and 5 to 6 pairs (original description of holotype says 2 pairs) of long setae (2ML;2mc1,2,3+2MC;±2d1); ML setae unusually long. Scutellum rounded, 1.4 times as long as mesoscutum with several rows of short, narrow longitudinal cells between placoid sensillae, becoming slightly wider and broader laterally. ISD:PSD ratio 7:1. Axillae areolae elongate and hexagonal. Axilla setae long, about 0.5 times as long as axilla length, and located apically. Gaster ovate, 1.25 times as long as thorax. Ovipositor elongate, as long as midtibia and arising at level of tergum I, distinctly exserted. Valvula III pale, 1.94 times longer than wide, about 0.38 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: 1.07, 3.15, 1.15, 1.00, 1.54, 1.54, 1.61, 1.85; length/width ratios: 2.33, 4.55, 1.67, 1.44, 2.22, 2.22, 2.33, 2.66. Club not distinct, linear sensillae present on all funicle segments. Forewing uniformly setose. Discal cell wide, 0.95 times as long as disk wide, rounded apically. Fringe short, 0.2 times as long as disk width. Marginal vein elongate, 1.23 times longer than submarginal vein. Basal group consists of 3-4 setae. Midtibial spur about 0.8-0.9 times as long as basitarsus II. Tarsal formula 5-4-5.

MALE: Unknown.

HOSTS: * Aleurodicus dispersus, Aleurothrixus floccosus (Westwood)

DISTRIBUTION: USA: HI^t; CUBA; HAITI; MEXICO; VENEZUELA.

NOTE: E. (?)haitiensis was introduced into Hawaii as a natural enemy of Aleurodicus destructor. Specimens of E. haitiensis reared from Aleurodicus dispersus may represent a distinct species (Polaszek et al. 1992) or possibly E. gallardoi.

Encarsia luteola Howard

(Figures 5.10:b,c)

Encarsia luteola Howard, 1895:29.

Encarsia deserti Gerling and Rivnay 1984:439. Synonomy by Polaszek et al. 1992:385.

Encarsia angelica Howard 1895:30. Synonomy by Polaszek et al. 1992:385.

HOLOTYPE: ♀ reared from Aleyrodes sp., Washington D.C., Aug. 14, 1881. In USNM (No. 26159) [Examined].

BIOLOGY: Morrill and Back, 1912; Poiner, 1964; Rivney and Gerling, 1987.

DIAGNOSIS: The female of E. luteola can be distinguished from other species of the formosa group by the following combination of characters: Occiput orange with base of head and thorax brown and gaster pale; interior of mesoscutal areolae with fine rugose striations; midtibial spur moderate about 0.7 times as long as basitarsus II. Biparental, males common.

FEMALE: 780-900 µm. Occiput very dark orange. Base of head,

pronotum, axillae, scutellum, metanotum, propodeum and hind coxae, dark brown. Central region of mesoscutum with dark brown V-shaped triangle and pale lateral margins. Gaster pale yellow. Antennae yellow, with scape, pedicel and F6 slightly fuscous. Forewing hyaline, except for small fuscous area at base of submarginal vein. Mesoscutum 1.6 times wider than long with 6 pairs of stout setae (2ML;2mc_{1,2,3}+2MC;2me₁); areolae hexagonal and elongate with fine striations in the interior spaces. Scutellum 0.75 times as long as mesoscutum, with several rows of narrow longitudinal cells between placoid sensillae, becoming wider broadly hexagonal laterally; ISD:PSD ratio 4:1. Axilla areolae elongate, setae located apically. Gaster somewhat elongate, 1.86 times as long as thorax. Ovipositor, slightly extruded, moderate in length, subequal to slightly longer than midtibia, arising at level of tergum IV. Valvular III pale, 2.18 times longer than wide and about 0.38 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: 1.07, 1.87, 1.00, 1.13, 1.27, 1.33, 1.4, 1.4; length/width ratios: 3.2, 2.57, 1.50, 2.14, 2.43, 2.71, 2.50, 2.63, 2.63; club 2-segmented, linear sensillae present on F 3-6; forewing uniformly setose, discal cell elongate, rounded apically, 1.13 as long as forewing width; fringe about 0.36 times maximum disk width; marginal vein elongate, 1.4 times longer than submarginal vein, 3-4 basal setae; midtibial spur about 0.5 times length of corresponding basitarsus, tarsal formula 5-4-5.

MALE: Head, mesoscutum, axillae and abdomen dark brown, scutellum

pale; wings hyaline; antennal segments subequal, very elongate, about 2 times longer than wide, F1 slightly wider; F5 and F6 separated, not fused; large basiconic setae on apex of F 1-5; thoracic sculpturing and setation and forewing characteristics similar to those of female.

HOSTS: ?*Aleurocybotus indicus*, *Aleyrodes* sp on willow (*Salix* sp.), *Bemisia tabaci*, * *Dialeurodinus* sp., *Aleurocybotus occiduus*, * *Trialeurodes abutiloneus*, *T. fernaldi*, *T. packardi*, *T. vaporariorum* (Westwood), * *T. variabilis*.

DISTRIBUTION: USA: AZ, CA, CT, DC, FL, MS, PA; BRAZIL; CHILE;
* COLOMBIA, GUADELOUPE; ISRAEL¹; MEXICO; PUERTO RICO; Introduced and established in ISRAEL.

Encarsia meritaria Gahan

(Figures 5.8:i,j,k)

Encarsia meritaria Gahan, 1927:19.

Encarsia hispida De Santis: 1948:45. Synonomy by Viggiani 1989:207.

[Removed from synonymy by Polaszek et al. 1992:383; synonymy as above confirmed by author].

HOLOTYPE: ♀ ex. *Trialeurodes floridensis* on *Persea americana* from Miami Beach, Florida (USA), May 12, 1924 by G. F. Mozzette. In USNM (Type No. 29445) [Examined].

DIAGNOSIS: The female of E. meritaria can be distinguished from other

species of the formosa group by its uniform orange body and cylindrical F1 antennal segment, slightly shorter than the F2 segment.

FEMALE: 600^a µm. Color nearly uniformly pale yellow. Eyes black. Antennae and legs pale. Wings hyaline. Mesoscutum elongate with elongate hexagonal areolae and 6 pairs of stout setae 2ML;2mc1,2,3+2MC;2md1). Scutellum 1.4 times as long as mesoscutum, with several rows of narrow longitudinal cells between placoid sensillae becoming wider broadly hexagonal laterally; ISD:PSD ratio to 4-5:1. Axilla setae located apically. Gaster subconical, 1.2 times as long as thorax. Ovipositor moderate in length, 1.0-1.2 times as long as midtibia, slightly extruded, arising at the level of tergum III. Valvula III pale, somewhat elongate, 4.0 times longer than wide and about 0.27-0.30 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: 1.1, 2.7, 1.2, 1.0, 1.6, 1.8, 1.8, 1.8, 1.9; length/width ratios: 1.00, 2.50, 1.11, 1.0, 1.00, 1.33, 1.33, 1.39, 1.67. Club 2-segmented, linear sensillae present on F 2-6, rarely on F1. Forewing uniformly setose. Discal cell somewhat elongate, about equal to maximum disk width, rounded apically. Fringe about 0.3 times as long as maximum disk width. Marginal vein elongate, 1.2 times longer than submarginal vein. Basal group consists of 3. setae. Midtibial spur about 0.75-0.80 times as long as basitarsus II. Tarsal formula 5-4-5.

MALE: Head with dusky with transverse bands on the occiput. Pronotum, basal part of mesoscutum and axillae, brownish. Gaster dark brown, except for a basal yellowish band. Funicle segments elongate, F5 and F6 slightly fused with the

following ratios to 0.6, 1.45, 0.5, 1.0, 1.0, 1.1, 1.1, 1.0, 0.9. Thoracic sculpturing and setation and forewing characteristics similar to those of female.

HOSTS: Aleuroglandulus malangae, Aleurothrixus porteri, Aleyrodes spiraeoides, * Dialeurodes sp., Siphoninus phillyreae, * Tetraleurodes acaciae, Trialeurodes abuilloneus, T. floridensis, T. vaporiorarum, * T. variabilis.

DISTRIBUTION: USA: FL, CA; BRAZIL; CHILE; COLOMBIA; DOMINICAN REPUBLIC; GUADELOUPE; HONDURAS; ITALY¹; JAMAICA; MEXICO; PUERTO RICO; SPAIN¹; VENEZUELA.

BIOLOGY: Avilla et al. (1991) reported that the American population of E. meritoria is biparental and the European population is uniparental. Gerling (1967) found that populations of E. meritoria were consistently high throughout the growing season of cotton in California.

NOTE: This species exhibits variation in the presence and absence of sensillae on the F1 segment, relative lengths of the antennal segments and color that varies from yellow to dusky. Although this species was described from Miami, Florida, it was very seldom reared in material collected in the Florida survey.

Viggiani's synonymy of E. meritoria with E. hispida was challenged by Polaszek et al. (1992) primarily on the basis of the partially fused male F5 and F6 antennal segment in E. meritoria, F5 and F6 being separated in males associated with E. hispida females collected in Brazil near the type locality. Males were not present in the type series of E. hispida. After a detailed examination of the respective paratype specimens of the two species, I am convinced that these species are synonymous based on the great similarities in relative body

measurements, wing shape and setation, ovipositor and valvular segments, setal type and position and sculpturing patterns of the mesoscutum. The male E. meritoria F5 and F6 are only very slightly fused. This character is generally fairly stable within a species; however I have observed variations in this character in large series of specimens. E. pergandiella males usually have the F5 and F6 separated, but they are partially fused in some individuals. The slight differences in the relative length of the F1 segment in the two species are likely to be host induced. The type series of E. meritoria was reared from Trialeurodes floridensis and E. hispida was reared from Bemisia tabaci. The relative lengths of antennal segments of E. formosa and E. pergandiella reared from T. vaporariorum were longer than those reared from B. tabaci. Therefore, the author supports Viggiani's synonymy of E. hispida with E. meritoria.

NOTE: E. meritoria is one of the most prevalent species reared in collections from Central and South America.

Encarsia variegata Howard

(Figure 5.10:a)

Encarsia variegata Howard, 1908:64.

Trichoporus variegata (Howard); Dozier 1933:92.

HOLOTYPE: ♀ reared from Aleurodicus (=Paraleyrodes) perseae on Citrus limon, Orlando, Florida (USA), June 25, 1907 by A. W. Morrill. In USNM (Type No. 11707) [Examined].

DIAGNOSIS: The female of *E. variegata* can be distinguished from other species of the formosa group by its color: head, mesoscutum, anterior margin of scutellum and lateral margin of gaster, are dark brown, with remainder of scutellum and gaster pale. F1 is very short, about 0.6 times as long as F2.

FEMALE: 640 µm. Head light brown with large dark brown, rectangular rugose area on occiput and red eyes. Mesoscutum, axillae, anterior margin of scutellum and lateral margin of tergites I-V of gaster, dark brown. Scutellum, gaster, antennae and legs, pale; wings hyaline. Mesoscutum very wide, 1.6 times times wider than long, with well-defined broad hexagonal areolae and 6-7 pairs of stout setae (2ML;2mc1,2,3,4+MC;2md1). Scutellum 0.9 times as long as mesoscutum with several rows of narrow longitudinal cells between placoid sensillae, becoming wider broadly hexagonal laterally; ISD:PSD ratio 6:1. Axillae areolae elongate, setae located apically. Gaster rather elongate, 2.0 times as long as thorax. Ovipositor moderate in length, 1.2 times longer than midtibia, slightly extruded, arising at level of tergite III. Valvular III pale, elongate, 6.0 times longer than wide, about 0.43 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: 1.5, 3.6, 1.4, 1.0, 1.8, 1.8, 1.9, 1.9, 1.8; length/width ratios: 2.83, 4.2, 1.8, 1.3, 2.2, 2.2, 2.2, 2.2, 2.0). Club 2-segmented, linear sensillae present on F 2-6. Forewing uniformly setose. Discal cell wide, equal to maximum disk width, apex rounded apically. Fringe short, about 0.16 times maximum disk width. Marginal vein 1.1 times longer than submarginal vein, 4 basal setae. Middibial spur long, about 0.84 times as long as basitarsus II. Tarsal formula 5-4-5.

MALE: Head, mesoscutum, axillae and gaster, dark brown. Scutellum pale, wings hyaline. Antennal segments very elongate, about 2.0 times longer than wide, with the following ratios to F1: 0.7, 1.6, 0.7, 1.0, 1.2, 1.2, 1.2, 1.2, 1.1; F5 and F6 separated, not fused. Thoracic sculpturing and setation and forewing characteristics similar to those of female.

HOSTS: * (?) Aleurocanthus woglumi, * Aleurodicus sp., * Aleurothrixus floccosus, Paraleyrodes perseae, Paraleyrodes naranjae.

DISTRIBUTION: USA: FL; CUBA; HAITI; * MEXICO; PUERTO RICO.

6.2.3. PARVELLA GROUP

(= E. parvella + E. pergandiella groups sensu Viggiani & Mazzone, 1979; = Aleurodiphus DeBach & Rose 1981.)

DIAGNOSIS: Tarsal formula 5-5-5. Forewing narrow with round aretose area under stigmal vein. Marginal fringe long, about equal to maximum disk width. ISD/PSD ratio greater than 2. Ovipositor moderate in length, not extruded. Antennal club 2-segmented. Aleyrodid parasitoids, cosmopolitan in distribution. Species belonging to this group have few setae on the mesoscutum ranging from 0 to 5 pairs (most species have 2 pairs). All are known only from aleyrodid host and are cosmopolitan in distribution. The group is similar to the cubensis group but is distinguished by its 5-segmented midtarsi, narrower forewing and long marginal fringe circumscribing the anterior and posterior margins of the disk. The parvella group is also very similar to the citrina group which are parasitoids of diaspine

scales but differs in lacking the striations on the petiole.

Encarsia americana (DeBach and Rose)

(Figures 5.11:a,b)

Aleurodiphus americanus DeBach and Rose 1981:660.

Encarsia americana (DeBach and Rose), Hayat 1983:70. New combination.

HOLOTYPE: ♀ reared from Aleurothrixus floccosus (Maskell) on Citrus sp., Santiago, Colima, Mexico, Jan. 21, 1975 by DeBach and Rose. In UCR. Reference specimens compared with paratype ♀ by A. Polaszek.

BIOLOGY: DeBach and Rose (1981).

DIAGNOSIS: The female E. americana is similar to E. pergandiella and E. basicincta in wing shape and setation, but differs from pergandiella by having 2 pairs of setae on the mesoscutum, shorter antennae, no linear sensillae on the F1 and F2 antennal segments, and a much shorter basitarsus on leg II. It differs from basicincta by lacking the prominent dark brown band on tergum I.

FEMALE: 740-960^a µm. Body yellow with prominent dark brown band on tergite I and faint infuscation on mesothoracic and metathoracic sternal areas; wings hyaline. Mesoscutum with weak elongate hexagonal areolae and 2 pairs (2ML:2MC) of setae. Scutellum 0.62 times as long as mesoscutum with 5 rows of narrow longitudinal cells becoming broadly hexagonal laterally; ISD:PSD ratio 5:1. Axilla areolae elongate and few, setae located apically. Gaster elongate 1.67 times longer than thorax. Ovipositor moderate in length, arising at level of

tergum IV, subequal to length of midtibia. Valvular III pale, narrow, and elongate, 2.11 times longer than wide and about 0.5 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: 1.1, 3.0, 1.3, 1.0, 1.3, 1.5, 1.6, 1.6, 1.7; length/width ratios: 1.0, 1.5, 1.8, 1.5, 1.6, 1.8, 1.9, 1.8. Club 2-segmented, linear sensillae present on F 2-6. Forewing narrow, with large roundish asetose area around stigmal vein extending to about mid-dis. Discal cell elongate, 1.33 times maximum disk width. Fringe long, about 0.47 times maximum disk width. Marginal vein 1.3 times longer than submarginal vein; 2 basal setae. Midtibial spur short, about 0.6 times as long as basitarsus II. Tarsal formula 5-5-5.

MALE: Resembles female in general morphology; posterior margin of head, small areas on face, anterior third of mesoscutum, axillae, propodeum and gaster black. Pedicel short, about 0.5 times as long as F1, segments F5 and F6 broadly joined, not fused.

NOTE: *E. americana* males develop as hyperparasites of *Amitus spiniferus*.

HOSTS: *Aleurothrixus floccosus*

DISTRIBUTION: BRAZIL; EL SALVADOR; * HONDURAS; MEXICO; PUERTO RICO.

Encarsia basicincta Gahan

(Figures 5.10:f,g,h)

Encarsia basicincta Gahan, 1927:20.

Encarsia basicincta Gahan, in DeBach & Rose 1981:666.

HOLOTYPE: ♀ reared from Aleurothrixus floccosus, San Juan, Puerto Rico, Jan. 3, 1925, by H. L. Dozier. In USNM (No. 29446) [Examined].

DIAGNOSIS: E. basicincta differs from other members of the parvella group by its conspicuous dark brown band on tergite I, and very short F1 segment.

FEMALE: 570 µm. Body yellow except for conspicuous dark brown band on tergite I and anterior third of axilla. Antennae slightly dusky, legs pale, wings hyaline. Mesoscutum elongate, 1.14 times longer than wide with weak elongate hexagonal areolae and 2 pairs (2ML,2MP) of setae. Scutellum 0.33-0.56 times as long as the mesoscutum with narrow longitudinal cells becoming broadly hexagonal laterally; ISD:PSD ratio 4:1. Axilla areolae elongate, with short stubby setae, located apically. Gaster elongate, 1.4 times longer than thorax. Ovipositor subequal to length of the midtibia, arising at the level of the tergite IV. Valvular III pale, narrow and elongate, 2.53 times longer than wide and about 0.57 times as long as ovipositor (subequal to valvular II). Antennal segments R-F6 in the following ratios to F1: 1.25, 2.75, 1.25, 1.00, 1.41, 1.58, 1.67, 1.83, 1.91 3.0, 1.3, 1.0, 1.3, 1.5, 1.6, 1.6, 1.7; length/width ratios: 3.0, 4.7, 1.67, 1.71, 2.28, 2.37, 2.22, 2.44, 2.55. Club 2-segmented, linear sensillae present on F 2-6. Forewing narrow, with large roundish asetose area around the stigmal vein extending to about mid-disc. Discal cell elongate 1.45 times maximum disk width. Fringe long, 0.63 times maximum disk width. Marginal vein 1.3 times longer than submarginal vein; 2 basal setae. Midtibial spur short about 0.6 times as long as basitarsus II. Tarsal formula

5-5-5.

MALE: Unknown.

HOSTS: * Aleurodicinae, Aleurothrixus floccosus, Tetraleurodes ursorum.

DISTRIBUTION: USA: * FL; PUERTO RICO.

Encarsia pergandiella Howard

(Figures 5.10:c,d,e)

Encarsia pergandiella Howard, 1907:78.

Encarsia versicolor Girault 1910:53. Synonymy by Gahan, (in Peck 1951:438).

Encarsia bemisiae De Santis 1981:37, preoccupied by Prospaltella bemisiae Ishii (1938).

Encarsia tabacivora Viggiani 1985:82, replacement name for bemisiae De Santis.

Encarsia tabacivora Viggiani. Synonymy by Polaszek et al. 1992:387.

HOLOTYPE: ♀ reared from Aleyrodes sp. on Xanthium strumarium, Sep. 25, 1900, Washington, D.C. by T. Pergande. In USNM (Type No. 10302) [Examined].

BIOLOGY: Gerling (1966).

DIAGNOSIS: E. pergandiella differs from other members of the parvella group by the brownish inverted triangular spot (more conspicuous in male) covering the central region of the mesothorax; 4 to 5 pairs of mesoscutal setae; and slightly infuscate forewing.

FEMALE: 580 µm. Body uniformly honey yellow, with brownish inverted

triangular spot on mesoscutum (color variation includes dusky abdominal bands).

Legs and antennae pale, wings hyaline; Mesoscutum with numerous weak elongate hexagonal areolae and 4-5 pairs of setae (2ML;2mc2,3+2MC;±2mc4) in holotype and specimens reared from *Trialeurodes* species; larger and broader areolae and usually no more than 4 pairs of setae in specimens reared from *B.* *tabaci*. Scutellum 0.72 times as long as mesoscutum with narrow longitudinal cells becoming broadly hexagonal laterally; ISP:PSD ratio 5:1. Axilla areolae elongate with setae located apically. Gaster 1.66 times as long as thorax. Ovipositor subequal to length of midtibia (shorter than midtibia in most *B. tabaci* reared specimens), arising at level of tergum III. Valvular III pale, 2.0 times longer than wide and about 0.36 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1 (holotype): 1.1, 2.6, 1.1, 1.0, 1.2, 1.4, 1.5, 1.5, 1.8; length/width ratios: 3.0, 6.6, 2.5, 2.3, 2.8, 3.0, 3.0, 2.9, 3.0. Club 2-segmented, linear sensillae present on F 3-6. Forewing narrow, with large round asetose area around stigmal vein extending to about mid-disc. Discal cell elongate 1.55 times maximum disk width. Fringe long about 0.74 times maximum disk width. Marginal vein 1.3-1.4 times longer than submarginal vein; 2 basal setae. Midtibial 0.38 times as long as basitarsus II. Tarsal formula 5-5-5.

MALE: Resembles female in setation and sculpturing. Males smaller than females, inverted brownish triangle on the mesoscutum is more conspicuous. Axillae and gaster dark brown, scutellum dusky, forewing infuscate under the marginal vein. F5 and F6 broadly joined and separated, very rarely partially fused.

Hyperparasitoid of conspecific females or other parasitoid species in the whitefly host.

HOSTS: (?) Aleyrodes sp.; * Aleurodicus dispersus;

- * Aleuroglandulus malangae; Aleuroplatus coronatus; * A. elemerae,
- * Aleurothrixus floccosus, * Aleurotrachelus trachoides, Bemisia tabaci (Genn.);
- * Dialeurodes citri, * D. kirkaldyi, Trialeurodes abutiloneus (Hald.); * T. floridensis,
T. vaporariorum (Westwood), T. variabilis.

DISTRIBUTION: USA: CA, FL, GA, IL, NY, SC, Wash. DC; BRAZIL;
COLOMBIA; COSTA RICA; EL SALVADOR; GRENADA; GUADELOUPE;
GUATEMALA; HONDURAS; ITALY; MEXICO; PUERTO RICO; VENEZUELA.

NOTES: On the slide containing the E. pergandiella holotype specimen, was also mounted one adult male whitefly specimen, determined as Trialeurodes ?vaporariorum by Dr. Avas Hamon of the Division of Plant Industry, Gainesville, Florida. This evidence, along with the host and locality data for the holotype, strongly suggest that the original host for this species was T. vaporariorum. By far, this is the most prevalent parasitoid species reared from B. tabaci in all of the areas surveyed throughout Florida, the Caribbean and Latin America.

The synonymy of this species with E. tabacivora was not inherently evident. The type specimens differ considerably in the relative length of the F1 antennal segment, the coloration of the gaster and the mesoscutal sculpture. The holotype of E. pergandiella was reared from T. vaporariorum. The body and antennal segments are elongate (especially the scape), there are more mesoscutal

areolae and setae than type specimens of *E. tabacivora* which were reared from *B. tabaci*. Through the examination of several hundreds of specimens collected in different areas and on different hosts, it was possible to ascertain that the two were the same species and the variation that was observed was host or environmentally induced. Intermediate forms were found that had intermediate relative lengths of the antennal segments as well as light and dark forms. Similar variations in the relative length of antennal segments and sculpturing patterns of the mesoscutum were observed in *E. formosa* reared from *T. vaporiorarum* versus those reared from *B. tabaci*.

Encarsia lanceolata Evans, spec. nov.

(Figure 5.12:a,b,c,d,e)

DIAGNOSIS: *E. lanceolata* differs from other members in the *parvella* group by the broad lanceolate setae on the apex of the valvular III and much sparser forewing setae.

HOLOTYPE FEMALE: 0.580 mm (0.550 - 0.600 mm). Occiput yellow and base of head dark brown, eyes red. Pronotum and axilla dark brown. Mesoscutum with large bell-shaped, dark brown spot in the center, with lateral regions and scutellum light brown. Gaster pale except for dusky tergites I-III. Antennae and legs pale. Wings hyaline with very slight infuscation at wing base. Head with rugose sculpturing between compound eyes, distal segment of maxillary palps very elongate. Mesoscutum 1.3 times longer than wide with about 7

longitudinal and 14 transverse rows of weak elongate hexagonal areolae and 2 pairs (2ML;2MC) of setae. Scutellum 0.6 times as long as mesoscutum with row of 3 narrow longitudinal cells becoming broadly hexagonal laterally; two longitudinal lines crossing the medial region; Sc 1 setae long, reaching Sc 2 base; ISD:PSD ratio 2.6:1. Axillae short with few (about 4 in a longitudinal row) areolae, setae located apically. Endophragma short and rounded, reaching base of tergite II. Gaster 1.8 times longer than thorax with lateral margins of tergites II-V imbricate, each tergite with one pair of long setae (gl 2-7). Central setae (gc 5-6) as long as lateral setae. Ovipositor widely separated from hind coxae with 2 pairs of ventral setae between them. Ovipositor moderate in length, subequal to length of midtibia, arising at level of tergite III. Valvulae III pale, 1.4 times longer than wide and about 0.41 times length of ovipositor. Antennal segments R-F6 in the following ratios to F1: 1.2, 3.0, 1.4, 1.0, 1.3, 1.8, 2.0, 2.1; length/width ratios: 2.4, 4.3, 1.8, 1.6, 2.0, 2.6, 2.6, 2.9, 3.0. See Appendix C for antennal segment measurements and statistics. Club 2-segmented, linear sensillae present on F 3-6. Forewing narrow, with large round asetose area around the stigmal vein extending to about mid-disc. Discal cell elongate about 1.4 times maximum disk width, setae sparsely distributed (anterior and posterior margins largely bare). Fringe long 0.8 times maximum disk width. Marginal vein 1.1 times longer than submarginal vein; 2 basal setae. Midtibial spur short about 0.40 times as long as basitarsus II. Hindtibial spur about 1.7 times as long as basitarsus III. Tarsal formula 5-5-5.

HOLOTYPE: ♀ reared from *Bemisia tabaci* on *Chamaesyce* sp.,

Mayaguez, Puerto Rico, 16 XI 1988 by F. D. Bennett. Deposited in USNM. Paratypes: 9 females (same collection data as holotype); 2 deposited in FSCA, 2 NHM, 2 USNM and 3 in author's collection. Also collected from Aleurotrachelus atratus on Bauhinia sp. Mayaguez, Puerto Rico, 15 XI 1988 by F. D. Bennett.

MALE: Unknown.

HOSTS: Bemisia tabaci, Aleurotrachelus atratus.

DISTRIBUTION: PUERTO RICO.

6.2.4. STRENUA GROUP

DIAGNOSIS: Tarsal formula 5-5-5. Forewing uniformly setose. ISD:PSD ratio less than or equal to 1:1. Club 2- or 3-segmented. Conical setae present on basitarsus II of many species.

Most of the described species in this group are light colored and have very long, often extruded, ovipositors. The strenua group is based primarily on the position of the scutellar sensillae which may not be indicative of a monophyletic grouping. This character is also found in E. bella and E. quercicola, that share many characteristics with species placed in the aurantii group. It is not clear how many species share this characteristic since it has not been mentioned in most of the species descriptions. I have separated the species that share this character into three different subspecies groups. Species belonging to the strenua subgroup have a 3-segmented antennal club, and the F1 at least 1.5 times longer than wide. They are generally orange or yellow in color and have hyaline forewings. The

placoid sensillae are kidney-shaped. Many species in this group have very long ovipositors and extruded abdomens. Members of the quercicola subgroup have 2-segmented antennal clubs, are generally dark brown or black and have infuscate forewings. The placoid sensillae are kidney-shaped. For most species, the F1 segment is short, less than 1.5 longer than wide. The ovipositor is long (at least equal to the length of the tibia II). The bella subgroup has round placoid sensillae and a 3-segmented antennal club; its only known member, E. bella, is dark in color and is a parasitoid of diaspine scales. There remains a wide range of variability among the species that are placed in the strenua group under this criterion, so the group may eventually have to be broken down into other species groups. There is the great disparity in the lengths of the ovipositors between species in this group. The ovipositor of E. armata is extremely long and the gaster extruded, while the ovipositor of E. citrella is very short and not extruded. A thorough cladistical study of the genus may provide more insight to the evolutionary history of the members of these species groups.

6.2.4.1. Subgroup Strenua

Encarsia citrella (Howard)

(Figures 5.14:a,b,c,d,e,f)

Prospaltella citrella Howard 1908:282.

Prospaltella citrella Howard, in Mercet 1912:186.

HOLOTYPE: ♀ reared from Aleyrodes coronatus, Orlando, Florida, USA

by A. W. Morrill. In USNM (Type No. 12164) [Examined].

DIAGNOSIS: *E. citrella* differs from other members of the *strenua* group by its yellow gaster with dark brown transverse bands on tergites III-V; infuscate area under the marginal vein of the forewing, and very short basitarsus.

FEMALE: 720 μ m. Body yellow, with dark brown transverse bands on tergites III-V. Eyes red (original description says black). Legs and antennae pale. Wings with large infuscate area under marginal vein. Mandible tridentate with large incised ventral tooth. Mesoscutum very wide, 1.68 wider than long with 3 pairs of setae (2ML;2mc₂+2MC) and numerous small broadly hexagonal areolae. Scutellum wide, 1.8 times as long as mesoscutum with 2-3 rows of narrow longitudinal cells in central region becoming broadly hexagonal laterally; placoid sensillae close together, ISD:PSD ratio less than 1:1; Sc 1 very short, about 0.5 times as long as Sc 2. Axillae areolae wide and hexagonal, setae located apically. Gaster 2.2 times longer than thorax with fine stippling on tergite II-V. Ovipositor arising at tergite III and 1.47 times longer than midtibia. Valvular III pale, 2.0 times longer than wide and about 0.25 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: 1.00, 2.66, 1.08, 1.00, 1.17, 1.25, 1.42, 1.42, 1.58 and length/width ratio of 2.4, 4.0, 1.3, 1.5, 1.75, 1.67, 1.89, 2.11. Club 3-segmented, linear sensillae present on F1-6. Forewing rather short with discal cell elongate, 1.09 times maximum disk width, rounded apically. Fringe long, 0.38 times as long as maximum disk width. Marginal vein 1.28 times longer than submarginal vein. Stigmal vein narrow and elongate; 3 stout basal setae.

Basitarsus very short, 3 times longer than wide with strong conical seta at apical end. Midtibial spur 1.13 times longer than basitarsus II. Tarsal formula 5-5-5.

HOSTS: Aleuroplatus coronatus Quaintance; Kermes sp. on Quercus undulata (questionable record), * Aleuroplatus elemerae, * Bemisia tabaci.

DISTRIBUTION: USA: AZ, CA, FL; CHILE.

NOTE: The specimen determined as E. citrella by Howard (1908) from Kermes sp. is very much like the specimen reared from Aleuroplatus elemerae. Specimens reared from Bemisia tabaci on peanut, Arachis hypogaei, Archer, Florida 15 VIII 1992 by H. MacAuslane, are identical to those reared from Aleuroplatus elemerae.

Encarsia pseudocitrella spec. nov.

(Figures 5.15:a,b,c,d)

DIAGNOSIS: E. pseudocitrella differs from most members of the strenua group by its yellow gaster with dark brown transverse bands on tergite II-V and infuscate area under the marginal vein of the forewing. It is most similar to E. citrella but can be distinguished by its very short valvular III segment, slightly longer basitarsus II, subequal funicle segments and the shape and extent of the dark brown abdominal patch.

HOLOTYPE FEMALE: 0.67 mm (0.58-0.72). Head bright orange, eyes black, body yellow with dark brown transverse band on tergites II-V. Legs and antennae pale; wings with large infuscate area under marginal vein. Mandibles tridentate with large incised ventral tooth. Mesoscutum very wide, 1.33 times wider

than long with 2 pairs of setae (2ML;2MC) and elongate hexagonal areolae. Scutellum wide, 2.1 times wider than long and 0.6 times as long as mesoscutum; placoid sensillae close together, ISD:PSD ratio less than 1:1; Sc 1 short and thin about 0.5 as long as Sc 2. Axillae areolae elongate and hexagonal, setae short and stubby, located apically. Gaster 1.5 times longer than thorax, lateral margins of tergites II-V imbricate. Ovipositor arising at level of tergite III and 0.93 times as long as midtibia. Valvular III pale, 0.93 times as long as wide and about 0.20 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: 0.78, 2.2, 0.78, 1.00, 0.93, 0.93, 1.07, 1.07, 1.43; length/width ratios: 2.44, 3.87, 1.10, 1.75, 1.63, 1.44, 1.50, 1.50, 2.00. See Appendix C for antennal measurements and statistics. Club 3-segmented, linear sensillae present on F1-6. Forewing rather short, with discal cell elongate and rounded apically 1.22 times maximum width of disk. Fringe long about 0.37 times maximum disk width. Marginal vein 1.18 times longer than submarginal vein; 3 basal setae. Basitarsus II 5.0 times longer than wide, midtibial spur 0.5 times as long as basitarsus II. Tarsal formula 5-5-5.

HOLOTYPE: ♀ reared from Bemisia tabaci on Chamaesyce hyssopifolia, Olinda, PE, Brazil, 18 V 1988, F. D. Bennett collector. Deposited in the USNM.
Paratypes: 3 females with same collection data as holotype.

MALE: Unknown.

HOSTS: Bemisia tabaci

DISTRIBUTION: USA: FL (Gainesville); BRAZIL.

Strenua group species occurring in the New World but described elsewhere.

Encarsia armata (Silvestri)

(Figures 5.13:a,b,c)

Prospaltella armata Silvestri, 1927:33.

Encarsia protransvena Viggiani, 1985:89. NEW SYNONOMY [Paratype examined].

HOLOTYPE: ex. Aleurolobus subrotundus, Langson, Indo-China. In UNP.

HOSTS: Aleurolobus subtundus, Dialeurodes citri, D. citrifolii, D. kirkaldyi.

DISTRIBUTION: VIETNAM; * USA; * PUERTO RICO.

MALES: Unknown.

NOTE: A paratype specimen of E. protransvena Viggiani was compared with specimens identified as E. armata by Dr. Andrew Polaszek who had compared them with the holotype of E. armata. The specimens are virtually indistinguishable morphologically from each other; both have been reared from the same host, Dialeurodes kirkaldyi. Therefore, I propose that E. protransvena Viggiani be considered a junior synonym of E. armata Silvestri.

Encarsia strenua (Silvestri)

(Figure 5.13:d,e,f)

Prospaltella strenua Silvestri, 1927:34.

Prospaltella citri Ishii, 1938:29. Synonomy by Polaszek et al. 1992:388.

HOLOTYPE: female, ex. Bemisia giffardii (Kotinsky), Macao. In UNP.

HOSTS: Bemisia giffardii, B. tabaci, Dialeurodes citri, D. citrifolii,

Trialeurodes packardi. Clausen (1934) provided the following additional host records: Aleurolobus subrotundus Silv., Aleuroplatus sp., Asterochiton sp. Mound (1976) added Rusostigma eugeniae.

DISTRIBUTION: USA: CA, FL; HONDURAS; HONG KONG; INDONESIA; JAPAN; MACAO; MALAYASIA; PUERTO RICO.

NOTE: The specimen I examined from the USNM labeled as E. strenua collected on Asterochiton sp. from Java by Clausen is undoubtedly E. transvena. E. strenua is very similar to E. armata in body shape and color. Silvestri, who described the two species, said that E. strenua had a more rounded mandible and a slightly shorter ovipositor than E. armata. However, according to Polaszek et al. (1992) the difference in the mandibles is probably an artifact. The characters that are used to separate these two species such as the length of the ovipositor and the number of setae on the mesoscutum, have been shown to vary among members of the same species.

Encarsia transvena (Timberlake)

(Figures 5.13:g,h,i;5.22:k)

Prospaltella transvena Timberlake, 1926:312.

Prospaltella sublutea Silvestri, 1931:20. Synonomy by Viggiani 1985:90.

Encarsia transvena (Timberlake), Viggiani 1985:90. New combination.

Prospaltella flava Shafee 1973:254, preoccupied by flavus (Compere), 1936:300.

Encarsia shafeei Hayat 1981:145, replacement name for E. flavus (Shafee)

synonymy by Hayat 1989:120.

Prospaltella bermisiae Ishii, 1938:30. Synonymy by Polaszek et al. 1992:388.

HOLOTYPE: ♀ reared from Trialeurodes vaporiorarum, Honolulu, Oahu, 20 VI 1916 by Timberlake. In BPBM [Paratype examined].

HOSTS: Aleurocybotus indicus, Aleurodicus dispersus, Bemisia tabaci,

* Dialeurodes citri, * D. citrifolii, Parabemisia myricae, * Tetraleurodes acaciae, Singhius hibisci, * Trialeurodes abutiloneus, T. vaporiorarum, * T. variabilis.
Psyllidae: Diaphorina citri (possibly as a hyperparasitoid of Tamarixia (=Tetrastichus) radiata (Eulophidae)).

DISTRIBUTION: Virtually cosmopolitan in the Old World, introduced into the USA: CA¹, FL¹; * BRAZIL; * GUADELOUPE; * HONDURAS; * MEXICO;
* PUERTO RICO; THAILAND.

6.2.4.2. Subgroup Quercicola

DIAGNOSIS: Tarsal formula 5-5-5. Forewing uniformly setose. Scutellar sensillae close together, ISD:PSD ratio 1:1 or less. Club 2-segmented. Most species with forewing infuscate and conical setae present on basitarsus II.

Encarsia catherinae (Dozier)

(Figures 5.17:f,g,h)

Trichoporus catherinae Dozier 1933:92.

Encarsia catherinae Dozier, in De Santis 1979:329, new combination.

HOLOTYPE: ♀ reared from Aleuroplatus catalpa on Haitian oak, Catalpa longissima at Damien, Haiti, Nov. 1, 1929 by H. L. Dozier. In USNM (Type No. 44820) [Paratype ♀ examined].

DIAGNOSIS: E. catherinae differs from other members of the quercicola group by the cylindrical F1 antennal segment, 1.9 times longer than wide and 0.9 times as long as F3, and pale hind coxae.

FEMALE: 730^a µm. Head and thorax yellow. Gaster dark brown except for extreme yellow tip. Legs and antennae pale except for F5-F6 dark antennal segment; wings infuscate from the marginal vein to frenal fold. Mesoscutum 1.57 wider than long with numerous small and elongate hexagonal areolae and 4 pairs of stout setae (2ML;2mc1,2+2MC. Scutellum 0.7 times as long as mesoscutum with broadly hexagonal areolae; ISD:PSD ratio 1:1 or less. Axilla areolae elongate with setae located apically. Gaster 1.6 times longer than thorax. Ovipositor elongate, 1.4 times as long as midtibia, arising at tergite II. Valvula II pale, elongate, 8 times longer than wide and about 0.4 times as long as ovipositor, with 8 pairs of apical setae. Antennal segments R-F6 in the following ratios to F1: 0.9, 2.3, 1.1, 1.0, 1.1, 1.2, 1.1, 1.1, 1.1, 1.1; length/width ratios: 2.5, 3.9, 1.7, 1.9, 2.1, 2.2, 2.1, 2.1, 2.1. Club 2-segmented, linear sensillae present on F 1-6. Forewing elongate subequal to maximum disk width. Discal cell broad and rounded apically. Fringe about 0.2 times maximum disk width. Marginal vein 1.1 times longer than submarginal vein; 4 basal setae in a row underneath the submarginal vein.

Basitarsus II with row of 4 conical setae, midtibial spur elongate, 0.95 times as long as basitarsus II. Tarsal formula 5-5-5.

MALE: Unknown.

HOSTS: Aleuroplatus catalpa.

DISTRIBUTION: HAITI.

Encarsia lycopersici De Santis

(Figures 5.16:d,e,f)

Encarsia lycopersici De Santis 1957:103.

HOLOTYPE: ♀ reared from aleyrodid on tomato, II-1956, La Plata, Argentina by Millan. In MNLP (Type No. ZA-97) [Paratype ♀ examined].

DIAGNOSIS: E. lycopersici differs from other species of the quercicola group by the elongate F1 segment about 2.6 times longer than wide, subequal in length to other funicle segments. E. lycopersici is most similar to E. coquillettii but differs primarily in the color of the gaster which is dark brown in coquillettii and yellow in lycopersici.

FEMALE: 600^a µm. Head and thorax (except for brown anterior margin), yellow. Pronotum and gaster, light brown. Legs and antennae dusky; eyes black. Wings weakly infuscated from the marginal vein to the frenal fold. Mesoscutum with numerous small and elongate hexagonal areolae and 4 pairs of stout setae (2ML;2mc2,3+2MC). MC setae very long, almost reaching Sc 1 base; ML, mc 2,3 rather short. Scutellum 0.9 times as long as mesoscutum with broad hexagonal

areolae; placoid sensillae close together, ISD:PSD ratio 1:0.5. Axilla areolae broad, hexagonal and numerous, seta short and located apically. Gaster 1.4 times as long as thorax. Ovipositor moderately elongate, 0.6 times as long as midtibia, arising at level of tergite III. Valvular III pale, about 0.33 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: 0.6, 1.6, 0.8, 1.0, 1.0, 0.9, 0.9, 0.85, 1.1; length/width ratios: 2.5, 4.2, 1.8, 3.2, 3.2, 3.0, 2.5, 2.3, 2.7. Club 2-segmented, linear sensillae present on F 1-6. Forewing elongate, discell cell broad, 1.1 times the maximum disk width, rounded apically. Fringe short, 0.18 times maximum disk width. Marginal vein 1.6 times longer than submarginal vein; 4 basal setae in a row underneath the submarginal vein. Basitarsus II elongate 10 times longer than wide, lacking conical setae. Midtibial spur elongate 0.4 times as long as basitarsus II. Tarsal formula 5-5-5.

MALE: Slightly darker in color than female. Antennal segments R-F6 in following F1 ratios: 0.6, 1.7, 0.6, 1.00, 1.05, 1.05, 1.02, 1.08, 1.23. All funicle segments elongate, length/width ratios: 3.0, 4.8, 1.6, 2.6, 3.0, 2.8, 2.9, 3.2, 3.5.

HOST: an aleyrodid on tomato (*Lycopersicum esculentum*)

DISTRIBUTION: ARGENTINA; CHILE

Encarsia portoricensis Howard

(Figures 5.16:a,b,c)

Encarsia portoricensis Howard, 1907:77.

Encarsia portoricensis Howard, in Viggiani 1987:105.

LECTOTYPE: ♀ designated by Viggiani, 1987:105, ex. Aleyrodes sp. on climbing vine, Bayamon, Puerto Rico, Jan. 1899, A. Busck collector. In USNM (No. 10301) [Examined]

DIAGNOSIS: E. portoricensis differs from other species of the quercicola group by having all the funicle segments subequal in length, tergites II-VI with 2 to 3 rows of spine-like structures, and triangular syntergum.

FEMALE: 1000^a µm. Head, posterior portion of mesoscutum, axillae, scutellum and lateral margins of gaster, yellow. Pronotum, anterior portion of mesoscutum and central region of gaster, brownish. Eyes and ocelli dark red (crimson). Legs and antennae pale; wings hyaline. Mesoscutum with 5 pairs of setae (2ML;2mc2,3,4+2MC). Scutellum placoid sensillae close together, ISD:PSD ratio 1:1 or less, Sc 2 setae very long. Gaster elongate, syntergum triangular 2 times as long as wide. Ovipositor elongate, arising at base of tergite I, extruded. Valvular III 0.25 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: ? (radicle), 2.0, 0.9, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0. Club 2-segmented, linear sensillae present on F 1-6. Forewing elongate with discal cell broad and rounded apically subequal to maximum disk width. Fringe short, 0.20 times maximum disk width; 6 basal setae in a row underneath the submarginal vein. Basitarsus short with elongate midtibial spur subequal basitarsus II length.

Tarsal formula 5-5-5.

MALE: Unknown.

HOSTS: Aleuroplatus sp., Aleurothrixus floccosus, Aleyrodes sp.,

Comstockiella sabalis Comstock [probably not the true host].

DISTRIBUTION: BERMUDA; DOMINICAN REPUBLIC; MEXICO;
PUERTO RICO.

NOTE: The specimens on the slide I borrowed from the USNM, identified by A. Gahan as E. portoricensis, differs from the original description and Viggiani's drawing by having the F1 much more elongate and has a distinctly 3-segmented club. The F2 segment is longer than either F1 and F3. These specimens are very similar to E. armata.

Encarsia quercicola (Howard)

(Figures 5.16:g,h,i)

Prospaltella quercicola Howard 1908:282.

HOLOTYPE: ♀ reared from Aleyrodes gelatinosus Cockerell on oak (Quercus sp.), Los Angeles, California, USA, IV 1908 by R. S. Woglum. USNM (Type No. 12163) [Paratype examined].

DIAGNOSIS: E. quercicola differs from other species of the quercicola group by the short F1 antennal segment, 1.75 times longer than wide and 0.73 times as long as F3 and dark brown hindcoxae and hindfemur.

FEMALE: 730 µm. Occiput black. Posterior portion of mesoscutum, axillae, and scutellum, yellow. Pronotum, anterior portion of mesoscutum and gaster, black. Ocelli dark red (crimson). Legs and antennae pale except for dark hind coxae and F6 antennal segment. Forewings infuscate from the marginal vein

to the frenal fold. Mesoscutum with numerous small broad hexagonal areolae and 5 pairs of setae (2ML;2mc_{2,3,4}+2MC). Scutellum 0.68 times as long as mesoscutum with placoid sensillae close together, ISD:PSD ratio 1:1 or less. Axilla areolae elongate, setae located apically. Gaster elongate 1.6 times as long as thorax. Ovipositor elongate, 0.83 times as long as midtibia, extruded, arising at level of tergite I. Valvulae III pale, elongate, 4.6 times longer than wide and 0.3 times as long as ovipositor, apex acute. Antennal segments R-F6 in the following ratios to F1: 1.0, 2.6, 1.0, 1.0, 1.0, 1.4, 1.4, 1.5; length/width ratios: 2.0, 3.6, 1.2, 1.8, 1.8, 1.8, 1.8, 1.8, 1.9. Club 2-segmented, linear sensillae present on F 2-6. Forewing elongate, discal cell broad, 1.1 times maximum disk width, rounded apically. Fringe about 0.4 times maximum disk width. Marginal vein 1.5 times longer than submarginal vein; 4 basal setae in a row underneath submarginal vein. Middibial spur elongate 0.9 times as long as basitarsus II. Tarsal formula 5-5-5.

HOSTS: Aleuroplatus coronatus (by Gahan, (in Peck 1951:438); Aleyrodes gelatinosus.

DISTRIBUTION: USA: CA.

6.2.4.3. Subgroup Bella

DIAGNOSIS: Tarsal formula 5-5-5. Forewing broad, with uniform setation. Placoid sensillae round and close together, ISD:PSD ratio 1:1 or less, central suture bisecting scutellum. Club 3-segmented. Ovipositor moderate in length. One species, E. bella currently placed in the group, described by A. Gahan (1924) from Chionaspis pinifoliae from Ann Arbor, Michigan, USA.

6.2.5. OPULENTA GROUP

DIAGNOSIS: Tarsal formula 5-5-5. Forewing uniformly setose. F1 usually short, less than 1.5 times longer than wide and considerably shorter than F2. Placoid sensillae widely separated, ISD:PSD ratio greater than 2:1. Antennal club 3-segmented. Parasitoids of aleyrodids.

The body and setae of many of the species in this group are very robust. Their ovipositors are often very long and extruded (greater than the length of the midtibia). The midtibial spur is very large and the mesoscutum usually has a strongly sculptured surface with numerous (more than 4 pairs) of stout setae. The axilla setae in some species are located in the center of the axilla. Body coloration is often dark brown or black and forewing infuscate. The third valvular is usually very long and slender and sometimes dark colored. Males of many opulenta group species have the F1 and F2 antennal swollen as in the lutea species group. The cladistical analyses presented herein, showed that the opulenta group was most closely related to the lutea group. All are parasitoids of aleyrodids.

Encarsia brasiliensis (Hempel)

(Figures 5.17:a,b,c,d,e)

Prospalta brasiliensis Hempel 1904:20.

Prospaltella brasiliensis (Hempel), in Costa Lima 1936:37.

Prospaltella brasiliensis (Hempel), in De Santis 1932:12.

Location of type specimen(s) unknown, probably originally described from Brazil.

DIAGNOSIS: E. brasiliensis is similar to E. opulenta. Grissell (1979) differentiated E. brasiliensis from E. opulenta by having tergites IV and V dark brown, whereas in E. opulenta, tergites IV-VI are dark brown. Type material and the original description for this species was not available. The following notes are from Dozier's (1932) redescription of E. brasiliensis based on specimens reared from Aleurothrixus floccosus from Haiti.

FEMALE: 470^a µm. Body yellow-orange except the vertex. Pronotum, anterior portion of the mesonotum and about one-third the length of the gaster just before its tip, light brown. Antennae pale brown, scape pale yellow. Ocelli red. Legs yellowish-white. Ovipositor tip black. Wings hyaline. Placoid sensillae widely separated. Gaster almost twice as long as thorax and strongly extruded. F1 short about 0.5 times length of pedicel or F2. Forewing disk broad, length subequal to maximum disk width. Fringe short about 0.16 times maximum disk width; 1-2 basal setae. Basitarsus II elongate 11.8 times longer than wide. Midtibial spur short, 0.53 times as long as basitarsus II. Tarsal formula 5-5-5 (original description says 5-4-5).

MALE: Similar to female but with F1 distinctly wider.

HOSTS: Aleurothrixus floccosus, (?) A. porteri.

DISTRIBUTION: USA: FL; BRAZIL; HAITI; MEXICO; PERU.

NOTE: Hayat (1989) believed that the character Grissell (1979) used to distinguish the two species was not very reliable. Color is known to vary in several species in this group. Hayat refrained from placing this species into synonymy with

E. opulenta since type material for E. brasiliensis was not available (apparently lost). The validity of this species is also questionable due to Hempel's statement that the midtarsi are 4-segmented. Figures 5.17:b,c,d,e were drawn from specimens matching the description of E. brasiliensis reared from Aleurothrixus species on Manihot esculentum. The female antennae of these specimens is similar to that of members of the tricolor group in having short, equal-size funicle segments with wide linear sensillae.

Encarsia townsendi Howard

(Figures 5.18:a,b)

Encarsia townsendi Howard, 1907:78.

Encarsia townsendi Howard, in Viggiani 1987:52.

LECTOTYPE: ♀ ex. Aleyrodes on coarse grass, Sangrillo del Chico, Tabasco, Mexico, June 19, 1897, C.H.T. Townsend collector. In USNM (No. 10303) [examined].

DIAGNOSIS: E. townsendi differs from most other species of the opulenta group by its hyaline forewing. It is most similar to E. clypealis in body conformation and coloration, but may be distinguished by its shorter valvular III segment.

FEMALE: 660 µm. Face and vertex orange-yellow, ocelli carmine, eyes dark red. Mesoscutum and gaster light brown with distal tip yellowish. Scutellum dull lemon-yellow; wings hyaline. Mesoscutum with elongate hexagonal areolae

and 4 pairs of stout setae (2ML;2mc1,2+2MC). Scutellum 1.3 times as long as mesoscutum; ISD:PSD ratio 3:1. Axilla areolae elongate, setae centrally located. Gaster 1.3 times as long as thorax. Ovipositor moderately elongate, arising at base of gaster, 1.6 times longer than midtibia. Valvular III brownish about 3.5-4.0 times longer than wide and about 0.35 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: 1.25, 4.37, 1.5, 1.0, 1.87, 2.0, 1.87, 1.87, (F5 and F6 not present); club 3-segmented(?), linear sensillae present on F 2-6. Forewing elongate with discal cell broad 1.1 times as long as maximum disk width, rounded apically. Fringe 0.22 times as long as maximum disk width. Marginal vein 1.3 times longer than submarginal vein; 1-2 basal setae. Midtibial spur 1.1 times longer than basitarsus II. Tarsal formula 5-5-5.

MALE: Unknown.

HOST: Aleyrodes sp.

DISTRIBUTION: MEXICO.

NOTE: The F5 and F6 funicle segments are missing from all of paratype specimens examined.

Opulenta group species occurring in the New World but described elsewhere.

Encarsia clypealis (Silvestri)

(Figures 5.19:g,h,i,j,k,l)

Prospaltella clypealis Silvestri 1928:28.

Encarsia clypealis (Silvestri), in Hayat 1989:30.

HOLOTYPE: ♀, VIETNAM, Coxon (Tonkin). In IEUN.

BIOLOGY: Clausen (1978), Flanders (1969).

HOSTS: Aleurocanthus inceratus, A. spiniferus, A. spinosus, A. woglumi,
Aleyrodes sp., [Lepidosaphes beckii, probably not the true host].

DISTRIBUTION: CHINA; INDIA; PAKISTAN; PHILIPPINES; VIETNAM;
introduced into Mexico and Florida from India.

Encarsia divergens (Silvestri)

(Figures 5.18:c,d,e,f)

Prospaltella divergens Silvestri, 1926:182.

Encarsia divergens (Silvestri), in Hayat 1989:56.

HOLOTYPE: ♀ reared from Aleurocanthus woglumi on Citrus sp.,
Singapore. In IEUN.

BIOLOGY: Flanders (1969).

HOSTS: Aleurocanthus citriperdus, A. longispinus, A. spiniferus, A. woglumi.

DISTRIBUTION: CUBA; MEXICO; INDIA; INDONESIA; SINGAPORE.

NOTE: E. clypealis parasitizes Aleurocanthus woglumi and other
Aleurocanthus species in India (Smith, 1950). E. divergens is usually a parasitoid
of minor importance as it is restricted to very wet climates. Males are rare.
Females prefer to oviposit in the first nymphal stage of A. woglumi.

Encarsia merceti Silvestri

(Figures 5.19:a,b,c,d)

Encarsia merceti Silvestri 1926:187.Encarsia merceti Silvestri, in Hayat 1989:81.HOLOTYPE: ♀ reared from Aleurocanthus woglumi on Citrus sp., Singapore. In IEUN.

BIOLOGY AND UTILIZATION: Clausen and Berry (1932), Flanders (1969).

HOSTS: Aleurocanthus citriperdus, A. spiniferus, A. woglumi.DISTRIBUTION: CUBA; INDIA; INDONESIA; MALAYSIA; PHILIPPINES; SINGAPORE; MEXICO¹.NOTE: According to Smith (1950), E. merceti is a minor parasitoid of Aleurocanthus woglumi, being dominated by other Prospaltella (=Encarsia) species or by Eretmocerus serius. Hayat (1989) placed E. merceti into its own species group along with E. bennetti based on the wide mouth fossa.Encarsia opulenta (Silvestri)

(Figures 5.18:g,h,i,j,k)

Prospaltella opulenta Silvestri, 1928:30.Encarsia opulenta (Silvestri) in Hayat 1989:31.HOLOTYPE: ♀ reared from Aleurocanthus inceratus Silvestri, Indochina: Van Phu, Tonkino [Vietnam]. In IEUN.

BIOLOGY: Flanders (1969), Clausen (1956).

HOSTS: Aleurocanthus inceratus, A. woglumi.

DISTRIBUTION: BAHAMAS; BARBADOS; EL SALVADOR¹; INDIA; INDO-CHINA; JAMAICA¹; MEXICO¹; NICARAGUA¹; PAKISTAN; VIETNAM.

NOTE: E. opulenta is a very versatile parasitoid, adapting to different climates. It is a bisexual species; the male:female sex ratio in the field is about 7:1. Mated females prefer to oviposit in first instar nymphs of Aleurocanthus woglumi. Males develop as hyperparasites. E. opulenta preferentially hyperparasitize host pupae containing Amitus hesperidum larvae rather than those containing female E. opulenta larvae. E. opulenta females are able to differentiate hosts that have already been parasitized by their own species based on chemical cues, but can not distinguish those given off by other species (Dowell et al. 1981). Silvestri (1928) reported Ablerus macrochaeta Silv. as a hyperparasite of E. opulenta.

Encarsia smithi (Silvestri)

(Figures 5.19:e,f)

Prospaltella smithi Silvestri 1926:179.

Encarsia smithi Silvestri, in Hayat 1989:37.

HOLOTYPE: ♀ reared from Aleurocanthus spiniferus Q. & B, Canton, China. In IEUN.

BIOLOGY: Clausen (1956), Clausen & Berry (1932), Flanders (1969).

HOSTS: Aleurocanthus citriperdus, A. spiniferus, A. woglumi; A.

spiniferus; [? *Bemisia tabaci*].

DISTRIBUTION: CHINA; CUBA; INDIA; JAPAN; MEXICO; PAKISTAN;
SRI LANKA.

NOTE: *E. smithi* is a bisexual species that reproduces uniparentally at the rate of two generations for each host generation. Its reproductive habits facilitate its ability to colonize and establish into new areas. First instar *P. smithi* larvae destroy the second instar *Eretmocerus serius* larvae as the latter enter the newly pupated host. Such competition reduced an 80% parasitization rate by *E. serius* to about 5%. *E. smithi* is dominated by *Encarsia opulenta* and *Amitus hesperidum*. The presence of *E. smithi* and *Eretmocerus serius* in Mexico probably facilitated the establishment of *E. clypealis* and *E. opulenta* by providing hosts for the production of males (Smith 1950).

6.2.6. INARON GROUP

DIAGNOSIS: Tarsal formula 5-5-5. Forewing uniformly setose. Scutellar sensillae widely separated, ISD:PSD ratio 2:1 or more. Club 2-segmented. Species in this group tend to have very elongate funicle segments, greater than 2 times longer than wide, and have several (5-10) basal setae on the forewing.

Encarsia lopezi Blanchard

(Figure 5.20:d,e,f)

Encarsia lopezi Blanchard 1940:18.

Encarsia lopezi Blanchard, in De Santis 1942:377.

COTYPES: 3 females and 3 males, reared from an aleyrodid on cabbage, Brassica oleracea capitata, Buenos Aires, Argentina, 10 V 1940, L. Cristobal collector. In UNLP.

DIAGNOSIS: E. lopezi differs from other species of the inaron group by the slightly infuscate forewing and dark brown tergites IV-VII.

FEMALE: 1,120^a µm. Body and legs yellow except for brown coxae, proximal 0.66 of femur and first three tergites of gaster. Tarsi and antennae very dusky. Forewings hyaline, basal fifth slightly infuscate. Marginal vein brownish. Mesoscutum wide, 1.4 times wider than long with polygonal reticulate sculpturing and 5 pairs of setae. Scutellum with narrow longitudinal cells in the central region becoming broadly hexagonal laterally; ISD:PSD ratio 3:1. Gaster lateral margins imbricate, tergites I, V, VI and II, III, IV with one and three lateral setae, respectively. Ovipositor 73 µm and extruded. Antennal segments R-F6 in the following ratios to F1: 0.72, 2.24, 0.94, 1.00, 1.12, 1.06, 1.06, 1.00, 1.09, length/width ratio: ? (radicle), 5.1, 2.0, 2.44, 2.55, 2.25, 2.12, 2.00, 2.48. Club 2-segmented, linear sensillae present on F 1-6. Forewing disk broad, length subequal to maximum width. Fringe short about 0.16 times as long as maximum disk width; 4-5 basal setae in a row underneath the submarginal vein. Marginal vein 1.35 longer than submarginal vein. Basitarsus II elongate 11.8 times longer than wide. Midtibial spur short, 0.53 times as long as basitarsus II. Tarsal formula 5-5-5.

MALE: Similar to female but with gaster completely brown. Pedicel short, funicle segments elongate: ?(radicle), 1.5, 0.47, 1.00, 1.12, 1.02, 1.00, 0.96, 1.02, length/width ratio: ?(radicle), 4.96, 1.28, 1.94, 2.18, 2.15, 2.31, 2.21, 2.85.

HOST: an aleyrodid.

DISTRIBUTION: ARGENTINA.

NOTE: I was unable to examine the cotypes of this species, however De Santis redescription and figures of the species are well detailed. *E. lopezi* appears to be very closely related to *E. inaron*. Examination of the cotypes would be necessary to determine its validity as a separate species or if it is a junior synonym of *E. inaron*.

NOTE: Hayat (1989) said that the identity and validity of the species considered to be related to *inaron* (ie. *lopezi*, *aleyrodis*, *longicornis*, *partenopea*, *siphonini*, *persequens*, *margaritiventris*, *azimi* and *gunturensis*) is a difficult problem to solve without study of relevant types and larger series of authentically determined species. All of these species appear to be similar morphologically and where hosts are known, are aleyrodid parasitoids. Differences are noted in the relative length of the antennal segments, dimension of the forewings, length of the marginal fringe, and slight differences in the color of the gaster and legs. These characters appear to be highly variable in this species.

Specimens reared from a *Trialeurodes* species in Florida have the funicle segments three times as long as wide and the fourth and fifth tergites of the gaster with brown bands. Based on these characters, the specimens would be identified

as *E. longicornis* Mercet, but are probably a variation of *E. inaron*. Although it is likely that *E. longicornis* is a junior synonym of *E. inaron*, I will refrain from placing them into synonymy until an examination of the type specimens can be made.

Inaron Group species occurring in the New World but described elsewhere.

Encarsia inaron (Walker)

(Figures 5.20:a,b,c)

Aphelinus inaron Walker, 1839:10.

LECTOTYPE: ♀ from Dublin?, England, Haliday collector [no other data].

In NMI. Lectotype designated by Graham, 1976:142.

Aphelinus idaeus Walker 1839:12. Synonymy by Graham, 1976:142.

Encarsia inaron (Walker), in Graham 1976:142. New combination.

Encarsia partenopea Masi 1909:32. Synonymy by Polaszek et al 1992:383.

Trychaporus aleyrodis Mercet 1930:196. Synonymy by Polaszek et al. 1992:383.

Ferriere's (1965) synonymy of Coccophagus bivittatus (Compere), Coccophagus krygeri Mercet and Coccophagus longifasciatus Howard with E. inaron was not accepted; all of these species remain in the genus Coccophagus.

HOSTS: Acaudaleyrodes citri, Aleyrodes elevatus, A. ionicae, A. proletella, A. singularis, Asterobemisia carpini, A. paveli, Bemisia tabaci, Bulgariaeurodes cotesii, Siphoninus immaculatus, S. phillyreae, Tetraleurodes hederae, Trialeurodes vaporariorum.

DISTRIBUTION: EUROPE; NORTH AFRICA; ASIA; USA: CA*, * FL.

Introduced into California for the control of Siphonius phillyreae

NOTE: E. inaron is very similar in coloration to E. formosa; the head, mesoscutum, axillae, scutellum and hindcoxae are dark brown contrasting with pale abdomen. The ovipositor is short and ovipositor plate quadrate.

6.2.7. LUTEA GROUP

DIAGNOSIS: Tarsal formula 5-5-5. Placoid sensillae widely separated, ISD:PSD ratio greater than 3:1. Valvular III segment dark brown, contrasting with pale valvulae II. Antennal club 3-segmented. Forewing uniformly setose. Male F5 and F6 segments fused, F1 and F2 swollen wider than the pedicel and other funicle segments. Most species in this group are parasitoids of aleyrodids. Diaspine scale parasitoids, E. perniciosi and E. elongata, could be placed in this group based on the above characters, but will be maintained in the aurantii group, based on other characteristics and their host association. The cladistic analyses presented herein showed that the lutea group was most closely related to the opulenta group.

Encarsia lutea (Masi)

(Figures 5.23:1,b,c,d,e,f,g)

Prospaltella lutea Masi 1910:25.

Prospaltella indica Shafee 1973:235. Synonymy by Hayat 1981:162.

Encarsia lutea (Masi), in Ferriere 1965:132.

SYNTYPES: 2 females, ex. Aleyrodes cystus on Cistus salvifolius, Campania, Portici, Italy. In MCGS.

HOSTS: Acaudaleyrodes citri, Aleurolobus niloticus, Aleurocanthus woglumi, Aleurolobus tunnni, Aleurotrachelus sp., Aleyrodes lonicerae, A. proletella, Asterobemisia carpini, Asterobemisia atraphaxidis, Bemisia hancocki, B. ovata, B. tabaci, B. salicaria, Bulgaleurodes cotesi, Dialeurodes sp., Pealius setosus, P. sp., Tetralicia sp., Trialeurodes abutiloneus, T. vaporariorum, Trialeurodes sp., [eggs of Heliothis zea and Trichoplusia ni].

DISTRIBUTION: * BRAZIL; INDIA; PAKISTAN; ITALY; USSR; Palearctic.

BIOLOGY: E. lutea is a major parasitoid species in the Old World. In Sudan, it parasitized 6 to 30% of the Bemisia tabaci pupae on cotton and made up 66% of the parasitoid complex. In Israel, it was reported to be the most dominant parasitoid on cotton (Gerling, 1980). Stoner and Butler (1965) reared males of this species from eggs of Heliothis zea and Trichoplusia ni (Lepidoptera).

NOTE: E. lutea is the only species in this species group to be found in the New World, therefore it can be distinguished by the characters given for the species group.

6.2.8. LAHORENSIS GROUP

DIAGNOSIS: Tarsal formula 5-5-5. Forewing uniformly setose. Placoid sensillae widely separated, ISD:PSD ratio more than 3:1. Antennal club 3-

segmented, F1 segment longer than pedicel or F2. These characters may not be indicative of a monophyletic group, species such as E. armata may share these characters but are placed in other species groups based on the balance or subjective weighting of characters shared with species of other groups.

Encarsia ciliata (Gahan)

(Figures 5.21:e,f)

Prospaltella ciliata Gahan 1927:28.

HOLOTYPE: ex. Aleurodicus sp. (undescribed), San Juan, Puerto Rico, Jan 10, 1925 by H. L. Dozier. In USNM (No. 29448).

DIAGNOSIS: E. ciliata differs from E. lahorensis by having the forewing setae more dense, the setae under the marginal vein coarser than disk setae, the Sc 1 setae long (not minute) and forewing slightly infuscate.

FEMALE: 900³μm. Head and thorax pale yellow. Antennal frons orange yellow. Occiput, pronotum, anterior margin of mesothorax, propodeum and gaster, brownish black. Legs mostly pale yellow or white; middle and hind coxae and basal half of hind femur blackish, base of hindtibia fuscous. Forewings hyaline with faint infuscate transverse band behind the marginal vein. Mesoscutum unusually setose with 11 pairs of setae. Gaster about as long as thorax. Ovipositor with sheaths slightly exserted. Valvular III 0.33 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: ?(radicle), 1.58, 0.58, 1.0, 0.75, 0.83, 0.83, 0.91, 0.83; length/width ratios: ?, 3.8, 1.16, 2.0, 1.5, 1.67, 1.43, 1.57, 1.67. Club 3-

segmented, linear sensillae present on F 1-6. Forewing elongate with discal cell broad and rounded apically. Setae dense and coarse under marginal vein. Fringe short about 0.16 times maximum disk width. Marginal vein shorter than submarginal vein; 7 basal setae in a row along posterior margin of submarginal vein. Basitarsus II with row of conical setae. Midtibial spur about as long as basitarsus II. Tarsal formula 5-5-5.

MALE: Unknown.

HOST: Aleurodicus sp.

DISTRIBUTION: PUERTO RICO.

NOTE: E. ciliata was not collected in the survey, although several collections were made from Puerto Rico from various whitefly species including Aleurodicus species. The number of setae on the mesoscutum, long F1 and short scape, profuse wing ciliation, strong conical setae on the basitarsus as well as the host it was reared from, all suggest that this species is very close to, if not actually a member of the genus Encarsiella.

Lahorensis Group species occurring in the New World but described elsewhere.

Encarsia lahorensis (Howard)

(Figures 5.21:a,b,c,d)

Prospaltella lahorensis Howard 1911:132.

Encarsia lahorensis Howard, in Hayat 1989:73.

LECTOTYPE: ♀ designated by Hayat 1981a: reared from Aleyrodes (=Dialeurodes) citri, Pakistan, Lahore, XI 1910, R. S. Woglum collector. In USNM (Type No. 12169).

BIOLOGY: Viggiani & Mazzone (1978), Nguyen & Sailer (1979).

HOSTS: * Aleurodicus dispersus, Dialeurodes citri, D. citrifolii, * D. kirkaldyi, (?) Aleyrodes (=Trialeurodes) ricini.

DISTRIBUTION: Introduced USA¹; AL, AR, CA, FL, GA, LA, MS, NC, SC, TX; INDIA; ISRAEL, ITALY¹; PAKISTAN.

NOTES: E. lahorensis is well established in Florida as the major parasitoid species of D. citri and is easily distinguished from other species by its short Sc 1 setae, bare area around the posterior margin of the forewing, and dome-like reticulation pattern of the mesoscutum with only 2 setae.

6.2.9. PORTERI GROUP

DIAGNOSIS: Tarsal formula 5-5-5; placoid sensillae separated by distance of more than the diameter of one sensillum; antennal club 3-segmented, forewing uniformly setose; F1 segment shorter than pedicel or F2; ovipositor moderate in length, not extruded.

The porteri group, as it is defined here, is an assemblage of species that share the above characters but lack certain morphological characters that would place them in other species groups. Species placed in this group should be considered only tentative until the relationships between species can be better defined.

Encarsia porteri (Mercet)

(Figures 5.23:k,l)

Prospaltella citrella Howard ssp. porteri Mercet, 1927:130.

Prospaltella porteri Mercet, in Blanchard 1937:26.

Encarsia porteri (Mercet), in Polaszek 1991:102.

Encarsia porteri (Mercet), in Polaszek et al. 1992:387.

LECTOTYPE: ♀ designated by Polaszek et al. 1992: ex. Aleurothrixus granelli Blanchard, San Bernardo, Chile, Aug. 13, 1937, Mallo collector. In MNCN.

DIAGNOSIS: E. porteri can be distinguished from other Encarsia species by the combination of the characters given for the species group. In addition, its body is entirely yellow, and basitarsus II (6 times longer than wide) and axillae are very elongate.

FEMALE: 700 µm. Body lemon yellow. Eyes and ocelli red. Legs yellow. Mesoscutum, axillae, scutellum and tip of ovipositor slightly dusky. Forewing hyaline with marginal vein brownish. Mesoscutum 1.16 times longer than wide with 10 pairs of setae (2ML;2mc1,2,3+2MC) and numerous hexagonal areolae. Scutellum long with stout setae; ISD:PSD ratio 3:1. Endophragma short reaching tergum I. Gaster elongate about 1.6 times longer than thorax. Ovipositor rather short, 0.8 times as long as midtibia. Valvula III about 1.5 times longer than wide and 0.36 times as long as ovipositor. Antennal segments R-F6 in the following

ratios to F1: 1.26, 3.47, 1.29, 1.00, 1.18, 1.24, 1.13, 1.08, 1.42; length/width ratios: 4.00, 4.55, 2.13, 2.00, 2.14, 1.60, 1.39, 1.32, 1.74. Club 3-segmented, linear sensillae present on F 1-6. Forewing elongate, discal cell broad, 1.12 times maximum disk width, rounded apically. Fringe long, about 0.48 times the maximum disk width. Marginal vein 1.18 times longer than submarginal vein, 5-6 basal setae in a row along the posterior margin of the submarginal vein. Basitarsus II very elongate, 6 times longer than wide, conical setae lacking. Midtibial spur short, about 0.5 times as long as basitarsus II. Tarsal formula 5-5-5.

MALE: Not known.

HOSTS: Aleurocanthus sp., Aleurothrixus aepim (=A. granelli), A. porteri, Bemisia tabaci, Trialeurodes vaporiorarum.

DISTRIBUTION: ARGENTINA; BRAZIL; CHILE; * HONDURAS; PERU.

NOTE: Males of E. porteri have been reported (Rojas 1968) as facultative primary parasites in the eggs of various species of Lepidoptera.

Encarsia polaszeki, spec. nov.

(Figures 5.24:a,b,c,d)

DIAGNOSIS: E. polaszeki differs from porteri by its dark brown head, mesoscutum and lateral margins of the gaster.

HOLOTYPE FEMALE: 0.53 mm (0.450-0.55 mm). Head, central portion of mesoscutum, base of tergum I and lateral margin of gaster, dark brown. Eyes dark red. Axillae dusky, scutellum, lateral margin of mesoscutum, gaster, legs and

antennae, pale (F6 slightly darker); wings hyaline. Mandible tridentate, deeply incised. Mesoscutum 1.3 times wider than long with broad hexagonal areolae and 2 pairs of setae (2ML;2MC). Scutellum wide, 2.0 times wider than long and 0.62 times as long as mesoscutum; central region with elongate, narrow areolae; medial and lateral region areolae broad hexagonal; ISD:PSD ratio 2.75-3.0:1. Sc 1 not reaching Sc 2 base. Axillae areolae elongate and hexagonal with setae located apically. Endophragma short and broad, reaching tergum I. Gaster 1.68 times longer than thorax, lateral margins of tergites II-V imbricate. Ovipositor 0.94 times as long as midtibia, arising at base of tergum III. Valvular III pale, short, 1.16 times longer than wide and about 0.37 times as long as ovipositor. Antennal segments R-F6 in the following ratios to F1: 1.07, 3.28, 1.14, 1.0, 1.29, 1.43, 1.50, 1.43, 1.79; length/width ratios: 2.5, 4.60, 1.33, 1.55, 1.80, 2.00, 2.10, 2.00, 2.50. See Appendix C for antennal measurements and statistics. Club 3-segmented, linear sensillae present on F 2-6, elongate basiconic sensillae on F 1-3. Forewing discal cell elongate, 1.15 times as long as maximum disk width, rounded apically. Fringe long 0.5 times as long as maximum disk width. Marginal vein 1.20 times longer than submarginal vein; 2 basal setae. Midtibial spur 0.71 times as long as basitarsus II. Hindtibial spur 0.51 times as long as basitarsus III. Tarsal formula 5-5-5.

MALE: Similar to female in setation and sculpturing. Head, anterior portion of axillae, large round mesoscutal spot and gaster, dark brown. Funicle segments subequal in length about 1.6 times longer than wide. F5 and F6 fused.

HOLOTYPE: ♀ reared from *Bemisia tabaci* on *Chamaesyce hyssopifolia*.

Olinda, PE, Brazil, 18 V 1991, F. D. Bennett collector. In USNM. Allotype ♂ and 51 paratype females with same data as holotype deposited in USNM, FSCA, NHM and author's personal collection.

HOST: Bemisia tabaci.

DISTRIBUTION: BRAZIL.

NOTE: E. polaszeki is similar to members of the cubensis group in body shape, setation and sculpturing, differing primarily by its 5-segmented tarsi and uniformly setose forewing. It is provisionally placed in the porteri group based on the species group characteristics.

EYTMOLOGY: This species is named in honor of Dr. Andrew Polaszek of the Natural History Museum in London, for his contributions to the taxonomy of aphelinids and assistance in the identification of Encarsia species during the early phase of the Florida survey.

6.2.10. PLAUMANNI GROUP

DIAGNOSIS: Tarsal segment 5-5-5. Forewing uniformly setose. Placoid sensillae widely separated, ISD:PSD ratio 2:1 or greater. Funicle segments elongate more than two times longer than wide. Ovipositor as long or longer than midtibia. Maxillary palpi 2-segmented. Male F2 segment with large elliptical sensorial process. The plaumanni group is similar to the inaron group in antennal conformation, but its body shape, setation and sculpturing is similar to opulenta group species.

Encarsia plaumanni Viggiani

(Figures 5.22:f,g,h,i)

Encarsia plaumanni Viggiani 1987:77.

HOLOTYPE: ♀, Brazil, Nova Teutonia, 16 IV 1941, F. Plaumann collector. In AMEI [Examined].

HOST: Not known.

DISTRIBUTION: BRAZIL.

NOTES: No host information is given for E. plaumanni, but its long ovipositor and narrow, elongate valvular III segment suggest that the host is probably an aleyrodid. E. plaumanni is similar to species in the inaron group in having very elongate funicle segments, but has a 3-segmented club. Viggiani (1987) stated that E. plaumanni is closely allied to E. alboscutellaris De Santis. I have examined the holotypes of both species and find them very distinct in antennal conformation, ovipositor length and sculpturing of the mesoscutum (see discussion of E. alboscutellum). E. plaumanni has two segmented maxillary palps, males of this species possess an unique elongate sensorial complex on the F2 antennal segment. For the combination of these characters, E. plaumanni is hereby placed in its own species group.

6.2.11. AURANTII GROUP

DIAGNOSIS: Tarsal formula 5-5-5. Forewing uniformly setose. Placoid sensillae widely separated, ISD:PSD ratio greater than 2:1. F1 short, often

subquadrate. Ovipositor short, not exerted (Figures 5.25:f,g,h,i). Ovipositor plate somewhat quadrate. Members placed in this group are mainly parasitoids of diaspine scales, but some species parasitize aleyrodids. At present, the aurantii species group is not well defined. Many of the species placed in this group share characteristics found in other groups such as the lutea and opulenta species groups.

Encarsia peltata (Cockerell)

(Figures 5.22:a,b,c,d,e)

Mimatomus peltatus Cockerell 1911:464.

Prospaltella peltatus (Cockerell), in Peck 1951:437.

HOLOTYPE: ♀ ex. Aleyrodes pruinosa euphoriarum on Euphorbia sp., Glenwood Springs, Colorado, USA. In USNM (No. 15695) [Paratypes examined].

DIAGNOSIS: E. peltata can be distinguished from other species in the aurantii group by the following combination of characters: 2-segmented maxillary palps, F2 longer than F1 or F3, marginal fringe short (about 0.10 times as long as maximum disk width), and F 5-6 of male separated not fused.

FEMALE: 670 µm. Body black with scutellum bright yellow. Legs pale yellow with hind coxae brown; forewing hyaline. Mesoscutum 1.6 times longer than wide with 7-9 pairs of setae 2ML;2mc_{1,2,3}+2MC;2md₁;2me₁;2mf₁;±1mc₄,±1md₃), and numerous, broad imbricate hexagonal areolae. Scutellum 0.8 times as long as mesoscutum, central region with 8 rows of small elongate hexagonal areolae,

ISD:PSD ratio 3:1. Axilla setal base centrally located, long and stout, nearly reaching axilla base. Gaster 1.1 times longer than thorax. Ovipositor short, about 0.33 as long as midtibia. Valvular III about 0.33 as long as ovipositor, gonostyli very thick. Ovipositor plate quadrate. Antennal segments R-F6 in the following ratios to F1: 0.66, 3.00, 1.13, 1.00, 1.33, 1.33, 1.33, 1.13, 1.27; length/width ratios of 2.00, 6.42, 1.70, 1.50, 1.67, 1.67, 1.43, 1.21, 1.36. Club 3-segmented, linear sensillae present on F1-6. Forewing elongate with discal cell very broad, 0.96 times as long as maximum disk width, rounded apically, with dense short setae. Fringe very short about 0.10 times as long as maximum disk width. Marginal vein 1.15 times longer than submarginal vein; 7-8 basal setae. Basitarsus rather short and lacking conical setae. Midtibial spur short about 0.56 times as long as basitarsus II. Tarsal formula 5-5-5.

MALE: All funicle segments subequal in length, F5 and F6 separated.

HOST: Aleyrodes pruinosa euphoriarum Cockerell.

DISTRIBUTION: USA: CO.

6.2.12. CITRINA GROUP

DIAGNOSIS: Tarsal formula 5-5-5. Forewing narrow with asetose area around the stigma vein. Marginal fringe long, about equal to or longer than the maximum disk width. Petiole striated. Placoid sensillae widely separated, ISD:PSD ratio 3:1 or more. Mesoscutum with 1-4 pairs of setae, weakly sculptured. Males not known in most species and rare in those that are known. All are parasitoids of diaspine scales.

6.2.13. INQUIRENDAGROUP

DIAGNOSIS: Tarsal formula 5-5-5. Forewing uniformly setose usually narrow with long marginal fringe. F6 segment long and tapering. Placoid sensillae widely separated, ISD:PSD ratio 3:1 or more. Basitarsus II short, less than 3 times longer than wide. Midtibial spur about equal in length to basitarsus. Parasitoids of diaspine scales.

6.2.14. PERFLAVAGROUP

The perflava group is not well defined. Members currently placed in this group (Hayat 1989) have 5-5-5 tarsal formulae, have long, narrow, uniformly setose forewings and are Old World in distribution.

6.2.15. ELEGANGROUP

The elegans group is not well defined. Members currently placed in this group (Hayat 1989) have 5-5-5 tarsal formulae, uniformly setose wings, and are known from the Old World.

6.2.16. TRICOLOR GROUP

The tricolor group has not been well defined. Members placed in this group (Hayat 1989) have 5-5-5 tarsal formulae, broad very setose wings, and short and broad, subequal, funicle segments bearing wide linear sensillae; all species are known only from the Old World.

6.2.17. SINGULARIS GROUP

DIAGNOSIS: Tarsal formula 5-4-5. Forewing narrow, uniformly setose. Placoid sensillae separated, ISD:PSD ratio 3:1 or more. Metanotum and petiole with striations. Club 3-segmented. Male F1 segment with special sensorial complex located in a concavity on the internal surface. Two Old World species, singularis and lilyingae, make up this group. The group is similar to the citrina group but differs in having 4-segmented tarsi on leg II and the forewing uniformly setose.

6.3. Encarsiella alboscutellaris (De Santis) comb. nov.

Encarsia alboscutellaris De Santis 1979:5.

HOLOTYPE: ♀ Loreto, Misiones, Argentina. In UNLP.

DIAGNOSIS: Tarsal formula 5-5-5. Forewing uniformly setose. ISD:PSD ratio greater than 2. F1 very elongate, about equal to the length of the scape and about 2 times as long as the pedicel. Mesoscutum aciculate with more than 10 pairs of setae.

HOST: Not known.

DISTRIBUTION: ARGENTINA.

DISCUSSION: E. alboscutellaris is an unique species; it bridges the gap between the genera Encarsia, Encarsiella and Dirphys. Based on the current generic concepts, it could justifiably be placed in any one of the three genera but would be considered to be an aberrent member of whichever genus it was assigned. Polaszek and Hayat (1992) reported that these three genera in most

cladistic analyses form a trichotomy. The relationship between them is very close. Hayat erected the genus Encarsiella (Hayat 1983), but later placed it into synonymy with Dirphys (Hayat 1989). Polaszek and Hayat (1992) re-established the genus stating that monophyly of the genus was supported by a single synapomorphy, the reduced stigmal vein.

The overall morphology E. alboscutellaris suggests that it is closer to Encarsiella species, and is most similar to Encarsiella tachii Polaszek and Hayat. The F1 segment is extremely elongate, about 4.0 times longer than wide and equal in length to the scape, the placoid sensillae are separated by a distance of more than their diameter, the thoracic setae are numerous and similarly distributed, and the margins of the ovipositor plate and valvulae are strongly defined. Unlike Encarsiella, but similar to Dirphys, the mesoscutum is aciculate, which is one of two characteristics that were given in support of monophyly of the genus (Polaszek & Hayat 1992). Unlike Dirphys, the placoid sensillae are well separated, the F5 and F6 segments are straight, not oblique, and the scutellum is reticulate. E. alboscutellaris is also similar to Encarsia, in that the axillae are shorter than the distance between their bases. However, unlike Encarsia, the mesoscutum is aciculate and has about 25 randomly scattered setae; and the F1 is extremely long. Encarsia species have reticulate sculpturing on the mesothorax and have a maximum of 18 setae on their mesoscutum (Hayat, 1989). The combination of characters found in Encarsiella alboscutellaris demonstrates the close relationship between these three genera.

6.4. Summary

Fifty-four Encarsia species are reported to occur in the New World; thirty-nine are parasitoids of aleyrodids, representing ten different species groups. Three new species, all parasitoids of the SPWF, are described herein. Thirteen new distribution (country) records and 35 new host records are given for New World Encarsia species. Thirty-eight species of whiteflies were sampled (see Appendix A) on 165 different host plants (see Appendix B).

CHAPTER 7

CLADISTICAL ANALYSES

7.1. Introduction

The genus Encarsia is a cosmopolitan group of parasitoids of aleyrodids and diaspine scales. Several authors have produced more or less comprehensive treatments of species and species-groups relationships (Hayat, 1989; Viggiani, 1987a). The relationship between species and their placement into species groups has sometimes been based on the sharing of a single character, or with little or no justification beyond saying that "this group seems to be related to...". No previous authors have studied the relationships within the genus Encarsia with an explicitly phylogenetic methodology. Polaszek and Hayat's (1992) phylogenetic analysis of the genera Encarsiella and Dirphys included a few species of Encarsia in their analysis, but were not the focus of the study.

The objectives of the study were to analyze the morphology of Encarsia species and determine the relationships of several species placed in various species groups; to evaluate the evidence for monophyly of the various species groups; and to evaluate the existing classifications of Encarsia species groups from a phylogenetic perspective.

7.2. Methods

7.2.1. Analysis

Data were analyzed by constructing the transformation series matrix using MacClade (Madison and Madison, 1992); the file was then exported to PAUP, Phylogenetic Analysis Using Parsimony (Swofford, 1990) for phylogenetic analysis. The most parsimonious phylogenetic trees were selected and exported to MacClade, which offers an enhanced ability for graphic manipulation of the selected phylogenetic trees.

Character polarity was based on outgroup comparison. Characters found in Encarsiella, for example the robust body, larger number of mesoscutal and forewing setae, and 5-segmented midtarsi were considered to be the more primitive or ancestral state since they are shared by several other aphelinid genera. Characters found in Pteroptrix, for example, the frail body, few mesoscutal and forewing setae, and reduction in the number of antennal and tarsal segments, were considered the advanced or derived state.

7.2.2. Terminal Taxa

The following cladistical study was based on 18 taxa (= OTU Observational Taxonomic Units) and 41 transformation series. Fifteen Encarsia species, representing twelve Encarsia species groups; Pteroptrix chinensis and Encarsiella aleurodici were selected to evaluate the relationships between the different species groups and their relationship to these two closely related genera. Encarsia

alboscutellaris (now transferred to Encarsiella) was included to evaluate its relationship to Encarsia and Encarsiella species.

Table 7.1. Selected species and species groups used in the phylogenetic analysis.

<u>Species</u>	<u>Species Group</u>
<u>Encarsia lounsburyi</u>	Citrina Group
<u>E. sankarani</u>	Inquirenda Group
<u>E. pergandiella</u>	Parvella Group
<u>E. nigricephala</u>	Cubensis Group
<u>E. formosa</u>	Formosa Group
<u>E. protransvena(=armata)</u>	Strenua Group
<u>E. citrella</u>	Strenua Group
<u>E. bella</u>	Quercicola Group
<u>E. peltata</u>	Aurantii Group
<u>E. opulenta</u>	Opulenta Group
<u>E. quercicola</u>	Quercicola Group
<u>E. berlesei</u>	Inquirenda/Berlesei? Group
<u>E. lutea</u>	Lutea Group
<u>E. porteri</u>	Porteri Group
<u>E. plaumanni</u>	Plaumanni Group
<u>E. alboscutellaris</u>	Encarsiella (transferred)
<u>Encarsiella aleurodici</u>	Outgroup
<u>Pteroptrix chinensis</u>	Outgroup

The genus Encarsia is comprised of more than 175 species. The genus exhibits a high degree of inter- and intraspecific variability ranging from species that are large, robust-bodied with numerous body and forewing setae, to species that are small, fragile, and with very few body and forewing setae. Encarsiella aleurodici and Pteroptrix chinensis were chosen because they represent genera that have characteristics similar to Encarsia species on each end of the variability spectrum. The body of Encarsiella aleurodici is robust, with a wide, very setose

forewing. The tarsi are 5-segmented and the mesoscutum has numerous setae (greater than 14 pairs). The genus is closely related to Encarsia species such as E. berlesei and E. coquillettii and apparently distant from species such as E. lounsburyi and E. sankarani on the other end of the spectrum. E. lounsburyi and E. sankarani, like Pteroptrix chinensis are small and fragil. The forewings are narrow with relatively few setae and a long marginal fringe. The mid-tarsi are 4-segmented and the mesoscutum is weakly sculptured with few setae (less than 3 pairs).

The species chosen as representatives of various species groups are given in Table 7.1.

Table 7.2. Data matrix used for phylogenetic analysis.

Name	1	2	3	4
Pteroptrix	1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1	1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1	1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1	1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Encarsiella	0 0 1 1 1 1 1 0 1 0 1 0 2 0 0 1 0 0 2 0 2 1 1 1 0 1 1 0 0 1 1 1 0 1 1 1 0 0 1	0 0 1 1 1 1 1 0 1 0 1 0 2 0 0 1 0 0 2 0 2 1 1 1 0 1 1 0 0 1 1 1 0 1 1 1 0 0 1	0 0 1 1 1 1 1 0 1 0 1 0 2 0 0 1 0 0 2 0 2 1 1 1 0 1 1 0 0 1 1 1 0 1 1 1 0 0 1	0 0 1 1 1 1 1 0 1 0 1 0 2 0 0 1 0 0 2 0 2 1 1 1 0 1 1 0 0 1 1 1 0 1 1 1 0 0 1
E. lounsburyi	0 0 0 0 1 1 0 0 0 0 0 0 0 1 0 2 0 0 2 1 2 0 1 0 0 2 0 1 0 0 1 1 1 1 0 0 0 0 1 1 1	0 0 0 0 1 1 0 0 0 0 0 0 0 1 0 2 0 0 2 1 2 0 1 0 0 2 0 1 0 0 1 1 1 1 0 0 0 0 1 1 1	0 0 0 0 1 1 0 0 0 0 0 0 0 1 0 2 0 0 2 1 2 0 1 0 0 2 0 1 0 0 1 1 1 1 0 0 0 0 1 1 1	0 0 0 0 1 1 0 0 0 0 0 0 0 1 0 2 0 0 2 1 2 0 1 0 0 2 0 1 0 0 1 1 1 1 0 0 0 0 1 1 1
E. sankarani	0 0 0 1 0 1 0 0 0 0 ? 0 1 2 0 0 2 0 2 ? 1 0 0 2 0 1 0 0 1 0 1 0 1 0 0 0 0 0 1 1 1	0 0 0 1 0 1 0 0 0 0 ? 0 1 2 0 0 2 0 2 ? 1 0 0 2 0 1 0 0 1 0 1 0 1 0 0 0 0 0 1 1 1	0 0 0 1 0 1 0 0 0 0 ? 0 1 2 0 0 2 0 2 ? 1 0 0 2 0 1 0 0 1 0 1 0 1 0 0 0 0 0 1 1 1	0 0 0 1 0 1 0 0 0 0 ? 0 1 2 0 0 2 0 2 ? 1 0 0 2 0 1 0 0 1 0 1 0 1 0 0 0 0 0 1 1 1
E. pergandeiella	0 0 0 1 0 1 1 1 0 0 0 1 1 0 2 2 0 2 1 1 0 1 1 1 2 0 1 0 1 0 1 0 0 0 0 1 0 0 0 1 1	0 0 0 1 0 1 1 1 0 0 0 1 1 0 2 2 0 2 1 1 0 1 1 1 2 0 1 0 1 0 1 0 0 0 0 1 0 0 0 1 1	0 0 0 1 0 1 1 1 0 0 0 1 1 0 2 2 0 2 1 1 0 1 1 1 2 0 1 0 1 0 1 0 0 0 0 1 0 0 0 1 1	0 0 0 1 0 1 1 1 0 0 0 1 1 0 2 2 0 2 1 1 0 1 1 1 2 0 1 0 1 0 1 0 0 0 0 1 0 0 0 1 1
E. nigricephala	1 0 0 0 0 1 1 0 0 1 1 1 1 2 0 0 1 0 1 1 1 0 1 2 0 0 0 1 0 0 0 1 0 0 0 1 0 0 1 0 0 1	1 0 0 0 0 1 1 0 0 1 1 1 1 2 0 0 1 0 1 1 1 0 1 2 0 0 0 1 0 0 0 1 0 0 0 1 0 0 1 0 0 1	1 0 0 0 0 1 1 0 0 1 1 1 1 2 0 0 1 0 1 1 1 0 1 2 0 0 0 1 0 0 0 1 0 0 0 1 0 0 1 0 0 1	1 0 0 0 0 1 1 0 0 1 1 1 1 2 0 0 1 0 1 1 1 0 1 2 0 0 0 1 0 0 0 1 0 0 0 1 0 0 1 0 0 1
E. protansven	0 0 1 1 1 1 1 0 0 0 ? ? 0 2 1 1 1 0 2 ? 2 1 1 0 0 0 0 1 0 1 0 1 1 0 0 1 0 0 0 1	0 0 1 1 1 1 1 0 0 0 ? ? 0 2 1 1 1 0 2 ? 2 1 1 0 0 0 0 1 0 1 0 1 1 0 0 1 0 0 0 1	0 0 1 1 1 1 1 0 0 0 ? ? 0 2 1 1 1 0 2 ? 2 1 1 0 0 0 0 1 0 1 0 1 1 0 0 1 0 0 0 1	0 0 1 1 1 1 1 0 0 0 ? ? 0 2 1 1 1 0 2 ? 2 1 1 0 0 0 0 1 0 1 0 1 1 0 0 1 0 0 0 1
E. citrella	0 0 0 0 0 1 1 0 1 1 8 8 0 8 1 2 0 0 1 1 2 8 2 0 0 0 0 0 0 0 0 1 0 0 1 0 0 0 0 0 1	0 0 0 0 0 1 1 0 1 1 8 8 0 8 1 2 0 0 1 1 2 8 2 0 0 0 0 0 0 0 0 1 0 0 1 0 0 0 0 0 1	0 0 0 0 0 1 1 0 1 1 8 8 0 8 1 2 0 0 1 1 2 8 2 0 0 0 0 0 0 0 0 1 0 0 1 0 0 0 0 0 1	0 0 0 0 0 1 1 0 1 1 8 8 0 8 1 2 0 0 1 1 2 8 2 0 0 0 0 0 0 0 0 1 0 0 1 0 0 0 0 0 1
E. coquillettii	0 0 0 1 1 1 1 1 1 0 1 0 2 0 1 0 0 2 0 2 1 1 1 0 0 1 1 0 0 1 1 0 0 1 0 0 0 0 1	0 0 0 1 1 1 1 1 1 0 1 0 2 0 1 0 0 2 0 2 1 1 1 0 0 1 1 0 0 1 1 0 0 1 0 0 0 0 1	0 0 0 1 1 1 1 1 1 0 1 0 2 0 1 0 0 2 0 2 1 1 1 0 0 1 1 0 0 1 1 0 0 1 0 0 0 0 1	0 0 0 1 1 1 1 1 1 0 1 0 2 0 1 0 0 2 0 2 1 1 1 0 0 1 1 0 0 1 1 0 0 1 0 0 0 0 1
E. formosa	1 0 0 1 1 1 1 1 0 1 0 1 0 1 0 2 0 0 1 0 0 1 2 1 2 0 0 0 1 0 1 0 1 0 0 1 0 0 0 0 1	1 0 0 1 1 1 1 1 0 1 0 1 0 1 0 2 0 0 1 0 0 1 2 1 2 0 0 0 1 0 1 0 1 0 0 1 0 0 0 0 1	1 0 0 1 1 1 1 1 0 1 0 1 0 1 0 2 0 0 1 0 0 1 2 1 2 0 0 0 1 0 1 0 1 0 0 1 0 0 0 0 1	1 0 0 1 1 1 1 1 0 1 0 1 0 1 0 2 0 0 1 0 0 1 2 1 2 0 0 0 1 0 1 0 1 0 0 1 0 0 0 0 1
E. berlesei	0 0 1 0 1 0 1 2 1 1 1 ? ? 0 2 0 0 0 0 1 2 ? 0 2 1 1 1 0 0 0 0 0 1 1 1 1 1 0 1 1 0 1	0 0 1 0 1 0 1 2 1 1 1 ? ? 0 2 0 0 0 0 1 2 ? 0 2 1 1 1 0 0 0 0 0 1 1 1 1 1 0 1 1 0 1	0 0 1 0 1 0 1 2 1 1 1 ? ? 0 2 0 0 0 0 1 2 ? 0 2 1 1 1 0 0 0 0 0 1 1 1 1 1 0 1 1 0 1	0 0 1 0 1 0 1 2 1 1 1 ? ? 0 2 0 0 0 0 1 2 ? 0 2 1 1 1 0 0 0 0 0 1 1 1 1 1 0 1 1 0 1
E. opulenta	0 0 1 0 0 0 1 0 0 1 1 0 0 1 0 2 0 0 0 2 2 2 1 1 2 1 0 1 0 0 1 1 1 1 1 1 1 0 0 0 1	0 0 1 0 0 0 1 0 0 1 1 0 0 1 0 2 0 0 0 2 2 2 1 1 2 1 0 1 0 0 1 1 1 1 1 1 1 0 0 0 1	0 0 1 0 0 0 1 0 0 1 1 0 0 1 0 2 0 0 0 2 2 2 1 1 2 1 0 1 0 0 1 1 1 1 1 1 1 0 0 0 1	0 0 1 0 0 0 1 0 0 1 1 0 0 1 0 2 0 0 0 2 2 2 1 1 2 1 0 1 0 0 1 1 1 1 1 1 1 0 0 0 1
E. querxicola	0 0 0 0 1 1 1 1 1 1 1 ? ? 0 2 1 2 0 1 1 2 ? ? 1 0 0 1 1 1 1 0 1 1 1 0 0 1 0 1 0 0 1	0 0 0 0 1 1 1 1 1 1 1 ? ? 0 2 1 2 0 1 1 2 ? ? 1 0 0 1 1 1 1 0 1 1 1 0 0 1 0 1 0 0 1	0 0 0 0 1 1 1 1 1 1 1 ? ? 0 2 1 2 0 1 1 2 ? ? 1 0 0 1 1 1 1 0 1 1 1 0 0 1 0 1 0 0 1	0 0 0 0 1 1 1 1 1 1 1 ? ? 0 2 1 2 0 1 1 2 ? ? 1 0 0 1 1 1 1 0 1 1 1 0 0 1 0 1 0 0 1
E. porteri	0 0 0 1 0 1 1 0 1 1 ? ? 0 2 1 1 0 1 0 0 ? ? 1 1 1 0 0 0 1 0 0 0 0 0 ? 1 0 0 0 0 1	0 0 0 1 0 1 1 0 1 1 ? ? 0 2 1 1 0 1 0 0 ? ? 1 1 1 0 0 0 1 0 0 0 0 0 ? 1 0 0 0 0 1	0 0 0 1 0 1 1 0 1 1 ? ? 0 2 1 1 0 1 0 0 ? ? 1 1 1 0 0 0 1 0 0 0 0 0 ? 1 0 0 0 0 1	0 0 0 1 0 1 1 0 1 1 ? ? 0 2 1 1 0 1 0 0 ? ? 1 1 1 0 0 0 1 0 0 0 0 0 ? 1 0 0 0 0 1
E. bella	0 0 0 1 0 1 1 0 0 1 0 1 0 2 0 2 0 1 0 1 0 1 1 1 0 0 0 1 1 0 0 1 1 0 1 0 0 0 1 0 1	0 0 0 1 0 1 1 0 0 1 0 1 0 2 0 2 0 1 0 1 0 1 1 1 0 0 0 1 1 0 0 1 1 0 1 0 0 0 1 0 1	0 0 0 1 0 1 1 0 0 1 0 1 0 2 0 2 0 1 0 1 0 1 1 1 0 0 0 1 1 0 0 1 1 0 1 0 0 0 1 0 1	0 0 0 1 0 1 1 0 0 1 0 1 0 2 0 2 0 1 0 1 0 1 1 1 0 0 0 1 1 0 0 1 1 0 1 0 0 0 1 0 1
E. lutea	0 0 0 0 0 0 1 0 0 1 1 0 0 1 1 2 0 1 0 1 0 1 2 2 1 1 2 0 0 0 0 0 0 1 0 1 0 0 0 0 0 1	0 0 0 0 0 0 1 0 0 1 1 0 0 1 1 2 0 1 0 1 0 1 2 2 1 1 2 0 0 0 0 0 0 1 0 1 0 0 0 0 0 1	0 0 0 0 0 0 1 0 0 1 1 0 0 1 1 2 0 1 0 1 0 1 2 2 1 1 2 0 0 0 0 0 0 1 0 1 0 0 0 0 0 1	0 0 0 0 0 0 1 0 0 1 1 0 0 1 1 2 0 1 0 1 0 1 2 2 1 1 2 0 0 0 0 0 0 1 0 1 0 0 0 0 0 1
E. peltata	0 0 0 1 0 1 1 0 1 1 0 1 0 1 0 1 0 0 0 0 0 0 2 1 1 1 0 1 1 0 1 0 1 0 1 0 0 1 0 1 0 0 1	0 0 0 1 0 1 1 0 1 1 0 1 0 1 0 1 0 0 0 0 0 0 2 1 1 1 0 1 1 0 1 0 1 0 1 0 0 1 0 1 0 0 1	0 0 0 1 0 1 1 0 1 1 0 1 0 1 0 1 0 0 0 0 0 0 2 1 1 1 0 1 1 0 1 0 1 0 1 0 0 1 0 1 0 0 1	0 0 0 1 0 1 1 0 1 1 0 1 0 1 0 1 0 0 0 0 0 0 2 1 1 1 0 1 1 0 1 0 1 0 1 0 0 1 0 1 0 0 1
E. alboscutellar	0 0 1 1 1 1 1 2 1 1 ? ? 0 2 0 2 1 0 0 1 ? ? 2 2 1 1 1 0 1 1 0 1 1 1 1 0 1 1 0 0 1 1	0 0 1 1 1 1 1 2 1 1 ? ? 0 2 0 2 1 0 0 1 ? ? 2 2 1 1 1 0 1 1 0 1 1 1 1 0 1 1 0 0 1 1	0 0 1 1 1 1 1 2 1 1 ? ? 0 2 0 2 1 0 0 1 ? ? 2 2 1 1 1 0 1 1 0 1 1 1 1 0 1 1 0 0 1 1	0 0 1 1 1 1 1 2 1 1 ? ? 0 2 0 2 1 0 0 1 ? ? 2 2 1 1 1 0 1 1 0 1 1 1 1 0 1 1 0 0 1 1

7.2.3. Characters and Character matrix

The data matrix used in the analysis is presented in Table 7.2.

Each character is referenced by a number. A description for each character and its associated states is given in Table 7.3. Ordered characters are indicated by an asterisk before the character and excluded characters are indicated by two asterisks following the character.

7.3. Results and Discussion

Figure 7.1 and 7.2 indicate the most parsimonious solution to the data matrix. Branch numbers (Figure 7.1) are used to refer to specific branches of the tree and are given in brackets [] in the text; the numbers on the branches (Figure 7.2) refer to the characters given in Table 7.3 and are given in the text in parentheses ().

The most parsimonious tree found in a heuristic search of 51836 different combinations of the character matrix had a length of 148, a consistency index (CI) of 0.35 and a retention index (RI) of 0.50. Characters (9,16,19,22) had homoplastic indices of 0.800 or more and were excluded from the analysis (Table 7.3 and 7.4). These characters are known to vary among species placed in the same species group. Characters showing the highest degree of consistency were the presence or absence of specialized sensoria on the male antennae, the presence or absence of striations on the petiole; and to a lesser degree, the fused F5 and F6 segment of the male antenna, the relative length of the F2 segment, the presence or absence of the asetose area under the stigmal vein, the number of mesoscutal

Table 7.3. Characters and character states.

- | | |
|---|---|
| 1. Number of tarsal II segments: | 21. Male F2 sensillae |
| (0) 5; (1) 4 | (0) absent; (1) round; (2) laterally expanded |
| 2. Number of tarsal III segments: | *22**. Gaster/thorax length |
| (0) 5; (1) 4 | (0) less than or equal to 1.1; |
| 3. Conical setae on basitarsus II: | (1) 1.2 to 1.6; (2) greater than 1.7 |
| (0) absent; (1) present | Mesoscutal setae (pairs): |
| *4. Basitarsus II length/width ratio: | (0) 6 or less; (1) 6 to 12; (2) more than 12 |
| (0) short, <3; (1) moderate, 3 to 5 | Mesoscutum/scutellum length: |
| (2) long, greater than 5x longer than wide | (0) scutellum narrow, < or equal to 0.6; |
| 5. F1:F2 ratio: | (1) scutellum broad, greater than 0.6 |
| (0) short, < 1.3; (1) moderate to long, > 1.3 | Intersensillar distance: |
| 6. F1 length/width: | (0) close, less than or equal to diameter of one placoid sensillum, (ISD/PSD <=1); |
| (0) short, less than 1.5; | (1) moderate, 1 to 4; (2) > 4 |
| (1) moderate to long, greater than 1.6 | Scutellar central sculpture: |
| 7. F2 length/width: | (0) narrow; (1) areolate |
| (0) short, less than 1.5; | Scutellum length/width: |
| (1) moderate to long, greater than 1.6 | (0) narrow, < 2 times longer than wide; |
| 8. Club segments: | (1) equal to or greater than 2 |
| (0) 3; (1) 2; (2) undifferentiated | Axilla setal base: |
| 9**. F1 sensoria: | (0) apical; (1) central |
| (0) absent; (1) present | Axilla size: |
| 10. F2 sensoria: | (0) short; (1) elongate |
| (0) absent; (1) present | Petiole: (0) smooth; (1) striated |
| 11. Male F5-F6: | Gaster length/metanotum width: |
| (0) separate; (1) fused; (?) not known | (0) gaster short to moderate, < or equal to 1.5; (1) long, greater than 1.5 |
| 12. Male funicle segments length/width: | Gaster color: |
| (0) short, less than 1.5; | (0) light; (1) dark |
| (1) moderate to long, greater than 1.5 | Gaster lateral margin sculpturing |
| 13. Forewing setae: | (0) smooth; (1) imbricate. |
| (0) uniform; (1) asetose area under stigmal vein | Ovipositor/midtibia length: |
| 14. Forewing setal density: | (0) ovipositor short, < or equal to length of midtibia; (1) long, > length of midtibia (>1.0) |
| (0) sparse; (1) moderate to dense | Valvular III color: |
| *15. Forewing disk length/width: | (0) pale; (1) dark |
| (0) broad, less than or equal to 1; | Valvular III/Ovipositor length: |
| (1) moderate, between 1 and 1.2; | (0) valvular III short, < or equal to 0.3x the length of the ovipositor; (1) long, > 0.3 |
| (2) narrow, > 1.2x longer than wide | Ovipositor extruded: |
| *16**. Marginal vein/submarginal vein: | (0) absent; (1) present |
| (0) short, less than or equal to 1; | Mesoscutum/scutellum color: |
| (1) moderate, between 1 and 1.2; | (0) uniform; (1) different |
| (2) long, greater than 1.2 | Host: |
| 17. No. basal setae: | (0) aleurodidae; (1) diaspine scale |
| (0) less than 3; (1) greater than 3 | Mesoscutal sculpturing: |
| *18. Fringe: | (0) broadly hexagonal areolae; (1) elongate areolae. |
| (0) short, less than 0.3x; | 41. No. funicle segments: |
| (1) moderate, 0.4-0.6x | (0) six; (1) five |
| (2) long, greater than 0.6x the disk width | |
| 19**. Forewing infuscate: | |
| (0) absent; (1) present | |
| 20. Midtibial spur | |
| (0) short, < or equal to 0.5x the length of the basitarsus; (1) moderate 0.5 to 0.75; | |
| (2) long, greater than 0.75x | |

setae, and the position of the placoid sensillae on the scutellum. Absolute and mean distances between taxa are given in Table 7.5.

Relationships between species were often not clear-cut. For example, an equally parsimonious tree, placed *E. citrella* on the same lineage as *E. lutea* and *E. opulenta*. The position of *E. porteri* was also variable; in one analysis it was closest to *E. protransvena* and in another analysis, it was closest to *E. lutea*.

The phylogenetic tree (Figure 7.2, 7.3) was rooted by the outgroup, *Encarsiella aleurodici*, which represented the more primitive or ancestral taxon. *Encarsia alboscutellaris*, transferred to *Encarsiella* herein, is very closely related to *Encarsiella aleurodici*. These species have very elongate F1 antennal segments (6), a large number of asymmetrically placed mesoscutal setae (23), very robust bodies, and very tall and elongate axillae (29). They differ from each other primarily by the absence of conical setae on tarsus II (3) and sensoria on the F1 antennal segment. Both of these characters are highly homoplastic and may vary in members of the same species group.

Encarsia berlesei is closely related to *Encarsiella* species, in having a very robust body, many mesoscutal setae as well as other characteristics. It differs from *Encarsiella* species primarily in having the F1 antennal segment and axillae shorter, smaller gaster to thorax ratio (22), fewer mesoscutal setae (23) and infuscate forewing (19). Hayat (1989) reluctantly placed *E. berlesei* in the *inquirenda* group based primarily for its long, tapering F6 segment, but recognized

that it may be better placed in a separate species group. Unlike Encarsiella species which are all parasitoids of aleyrodids, E. berlesei is a parasitoid of diaspine scales. However host relationships may have little significance in the phylogeny of the genus; E. berlesei and E. sankarani, both diaspine scale parasitoids, apparently are distantly related.

Encarsia coquillettii [15] differs primarily from E. berlesei by the narrow longitudinal sculpturing of the scutellum (26) and relatively shorter ovipositor (34). Like E. formosa and E. peltata, it has elongate funicle segments (6), a two-segmented antennal club (8), similar mesoscutal setation and sculpturing (23,40), and a broad, very setose forewing. Encarsia formosa and E. peltata are very closely related differing primarily by the number of tarsal segments of leg II (1) and the position of the axilla setae (28). Results indicate that the fusion of the apical tarsal segments probably was probably derived on more than one lineage, and consequently, this character, alone, is not sufficient to indicate closely related species.

The strenua group is defined primarily by the closely-placed placoid sensillae of the scutellum (25). Perhaps the character is overemphasized. Nevertheless, these species are grouped together in order to facilitate species identification. Subgroups of the strenua group differ primarily in the number of club segments and the shape of the placoid sensillae. Whether all of the species that have the placoid sensillae close together are closely related is debatable. E. citrella and E. quercicola, in other analyses, were grouped with E. lutea and E. formosa,

respectively. The phylogenetic distance between several species in these groups is large, shown by the number of autapomorphies listed on the branches. All of the members of this group are parasitoids of aleyrodids except for E. bella and E. koebelei.

Encarsia porteri appears to be closely related to members of the strenua group. It is light in color, has a distinct 3-segmented antennal club and similar setation and sculpturing of the mesoscutum as many members of the strenua subgroup.

Encarsia lutea [6] and E. opulenta [7] showed a close relationship. Both species have similar antennal configurations, especially in the male antennae (6,11,12). Both species have the third valvulae dark which is one of the major characters which is used to define the lutea group. The large number of character reversals on the opulenta branch [7] indicate that although these species share many characteristics in common they remain phylogenetically very separated. The major differences that separate these two species are the length of the ovipositor (34,37) and gaster (31), the presence of conical setae (3) and the width of the forewing disk (15).

Males of Encarsia nigricephala [5], like E. lutea and E. opulenta, have the F5 and F6 segments fused together. The F2 antennal segment of the male nigricephala is laterally expanded and has a unique, round sensorial complex. The F2 antennal segment of the male lutea is laterally expanded, but bears linear sensillae. The ovipositor, valvulae, forewing shape and fringe of E. nigricephala

and *E. lutea* are similar in their relative lengths. *Encarsia nigricephala* differs primarily from *E. lutea* in having a 4-segmented basitarsus II (1), fewer mesoscutal setae (23) and an asetose area under the stigmal vein (13). Results from some of the other cladistic analysis showed a close relationship between *Encarsia nigricephala* and *E. pergandiella*. The major character separating species to the left of branch [26] from *E. nigricephala* is the narrow width of the forewing disk (15) and long marginal fringe (18), and the relatively narrow scutellum (27), in the former. *Encarsia pergandiella* is separated from the other groups by a combination of characters, the 2-segmented club segment (8) and asetose area under the stigma vein (13). Species to the left of branch [27] are separated from *E. pergandiella* by the relative length of body parts (7,24,29), the striated petiole (30), the host relationships (40) and the number of mesoscutal setae (23). Several members of the *parvella* or *pergandiella* group have only few mesoscutal setae (0-2 pairs).

E. sankarani [3] differs primarily from *E. lounsburyi* and *Pteroptrix* by the completely setose forewing and short basitarsus II. *Encarsia lounsburyi* [2] showed a close relationship with *Pteroptrix chinensis* [1], both have relatively short basitarsi (4) and moderately long F1 antennal segments (5). The characters that separate these two species, the number of tarsal (1,2) and funicle segments (41), have historically been weighted more than other characters. *Pteroptrix* has not been mentioned in the literature as close relative to the genus *Encarsia*. *Encarsiella*, *Dirphys*, *Coccophagus* and *Coccophagoides*, that represent the more ancestral end of the *Encarsia* spectrum, are usually given as its closest relatives.

Table 7.4. Character diagnosis of Encarsia and outgroup species.

Character	Consistency Index (CI)	Homoplastic Index (HI)	Retention Index (RI)
1. Tarsus I	0.333	0.667	0.000
2. Tarsus II	1.000	0.000	0/0
3. Basitarsus conical setae	0.333	0.667	0.5
4. Basitarsus length/width	0.200	0.800	0.429
5. F1:F2 ratio	0.250	0.750	0.625
6. F1 length/width	0.500	0.500	0.500
7. F2 length/width	1.000	0.000	1.000
8. # Club segments	0.400	0.600	0.571
* 9. F1 sensoria	0.200	0.800	0.333
10. F2 sensoria	0.500	0.500	0.750
11. F5-6 male	1.000	0.000	1.000
12. F1-6 male	0.500	0.500	0.500
13. Forewing setae	0.333	0.667	0.333
14. Forewing density	0.667	0.333	0.875
15. Forewing shape	0.333	0.667	0.636
*16. Marginal vein/stigmal	0.200	0.800	0.333
17. # basal setae	0.333	0.667	0.333
18. Fringe	0.500	0.500	0.778
*19. Forewing infuscation	0.167	0.833	0.167
20. Tibia II spur	0.286	0.714	0.444
21. F2 male specialized	1.000	0.000	1.000
22. Gaster/thorax	0.286	0.714	0.286
23. # Mesoscutal setae	0.400	0.600	0.625
24. Mesoscutum/scutellum	0.500	0.500	0.667
25. Placoid sensilla dist.	0.500	0.500	0.800
26. Scutellar sculpture	0.333	0.667	0.500
27. Scutellum length/width	0.500	0.500	0.750
28. Axilla setae	0.250	0.750	0.500
29. Axilla size	0.250	0.750	0.500
30. Petiole	1.000	0.000	1.000
*31. Gaster/metanotum	0.200	0.800	0.333
32. Gaster color	0.333	0.667	0.750
33. Gaster sculpture	0.333	0.667	0.000
34. Ovipositor/tibia II	0.250	0.750	0.571
35. Valvular III color	0.333	0.667	0.333
*36. Valvular III/ovipositor	0.200	0.800	0.200
37. Ovipositor extruded	0.250	0.750	0.000
38. Mesoscutum/Scutellum	0.250	0.750	0.250
39. Host	0.333	0.667	0.500
40. Mesoscutal sculpture	0.500	0.500	0.750
41. # Funicle segments	1.000	0.000	0/0

* Excluded from analysis

Strict consensus (Figure 7.4) analysis of the taxa showed close relationships between Encarsia opulenta and E. lutea; Pteroptrix chinensis and E. lounsburyi; and E. formosa and E. lutea.

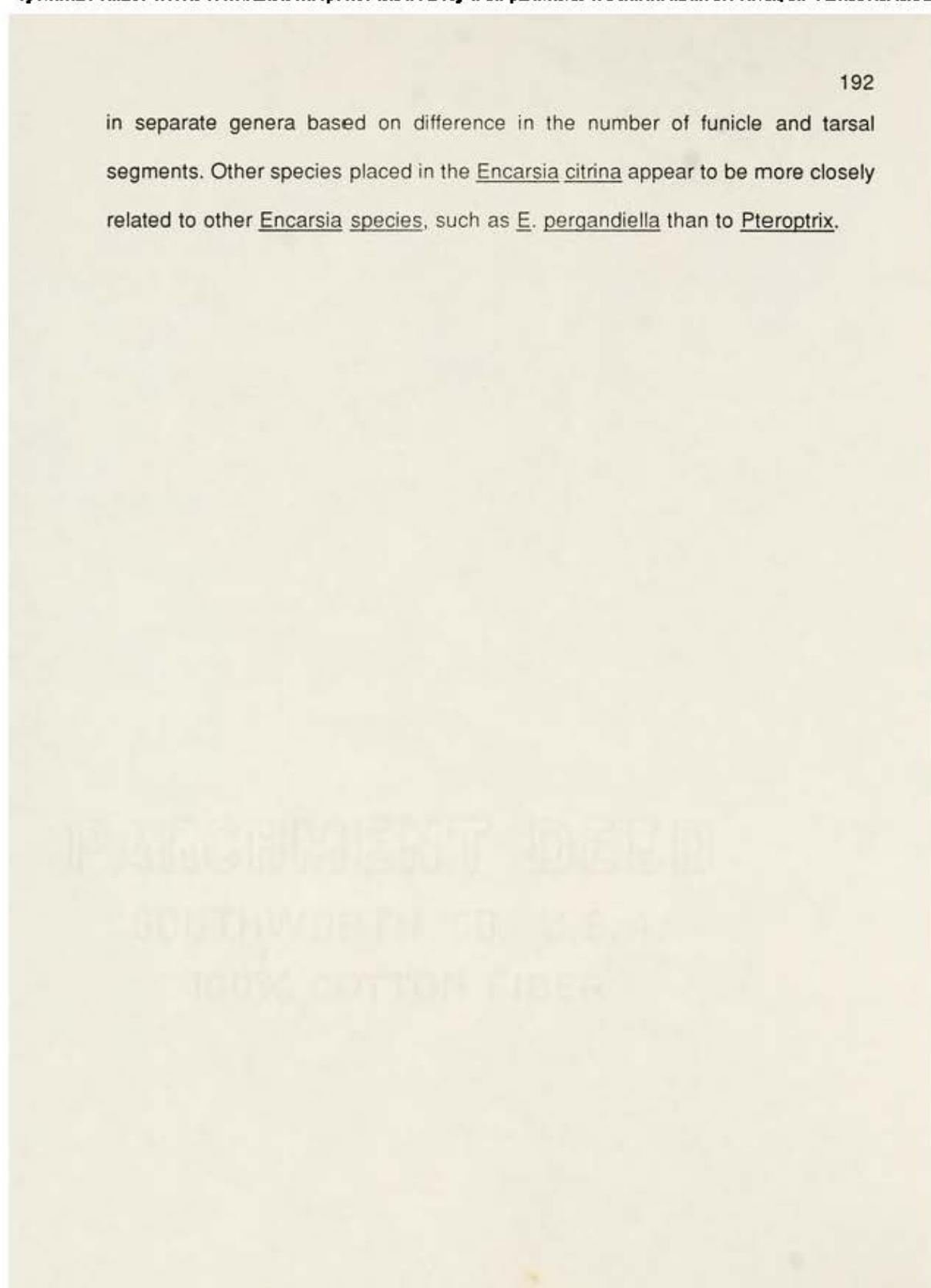
The present classification of Encarsia species, with few exceptions, is similar to that of the cladistic analysis. The high degree of homoplasy in the data make it difficult to draw any concrete conclusions between the relationships between the taxa. Figure 7.5 shows the large number of reversals of autapomorphies that occurred in this data set. The major points that were brought out by the cladistic study were:

- 1) the relative insignificance of the 4-segmented versus 5-segmented midtarsi in to phylogenetic relationships.
- 2) the ability to define the strenua group based on phylogenetic criteria.
- 3) the relative unimportance of host relationships to the phylogenetic analysis of the Encarsia species.
- 4) the closeness of the relationship between the genus Encarsia and Pteroptrix.

The phylogenetic significance of the 4-segmented versus the 5-segmented midtarsi is contingent upon whether species having this character share other characteristics as well. Species in the formosa group are apparently not closely related to species in the cubensis group. Species found within these groups are closely related to each other.

Although Encarsia lounsburyi and Pteroptrix chinensis were shown to be closely related based on the cladistic analysis, I believe that they should remain

in separate genera based on difference in the number of funicle and tarsal segments. Other species placed in the Encarsia citrina appear to be more closely related to other Encarsia species, such as E. pergandiella than to Pteroptrix.



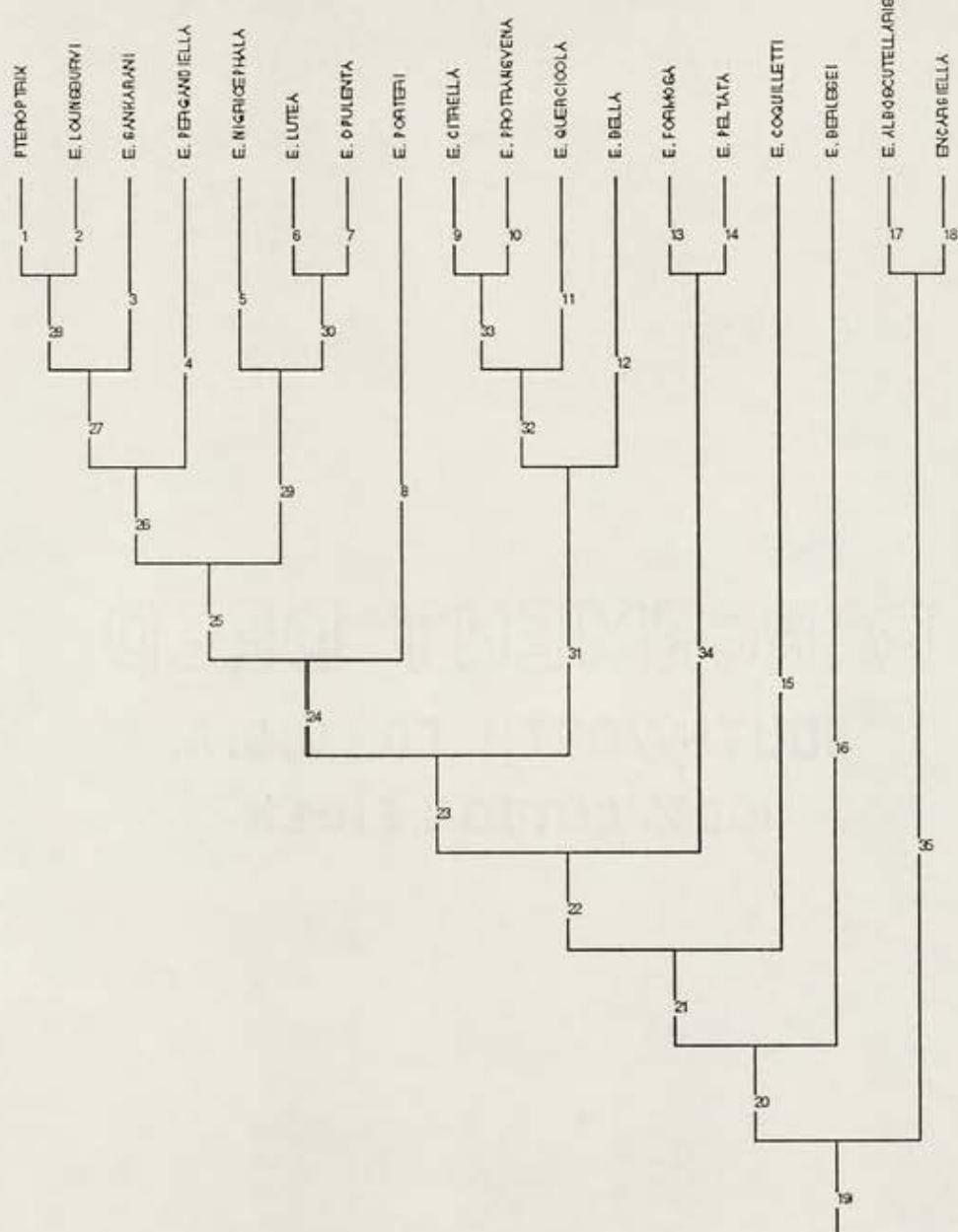


Figure 7.1. Branch numbers of most parsimonious solution to data matrix.

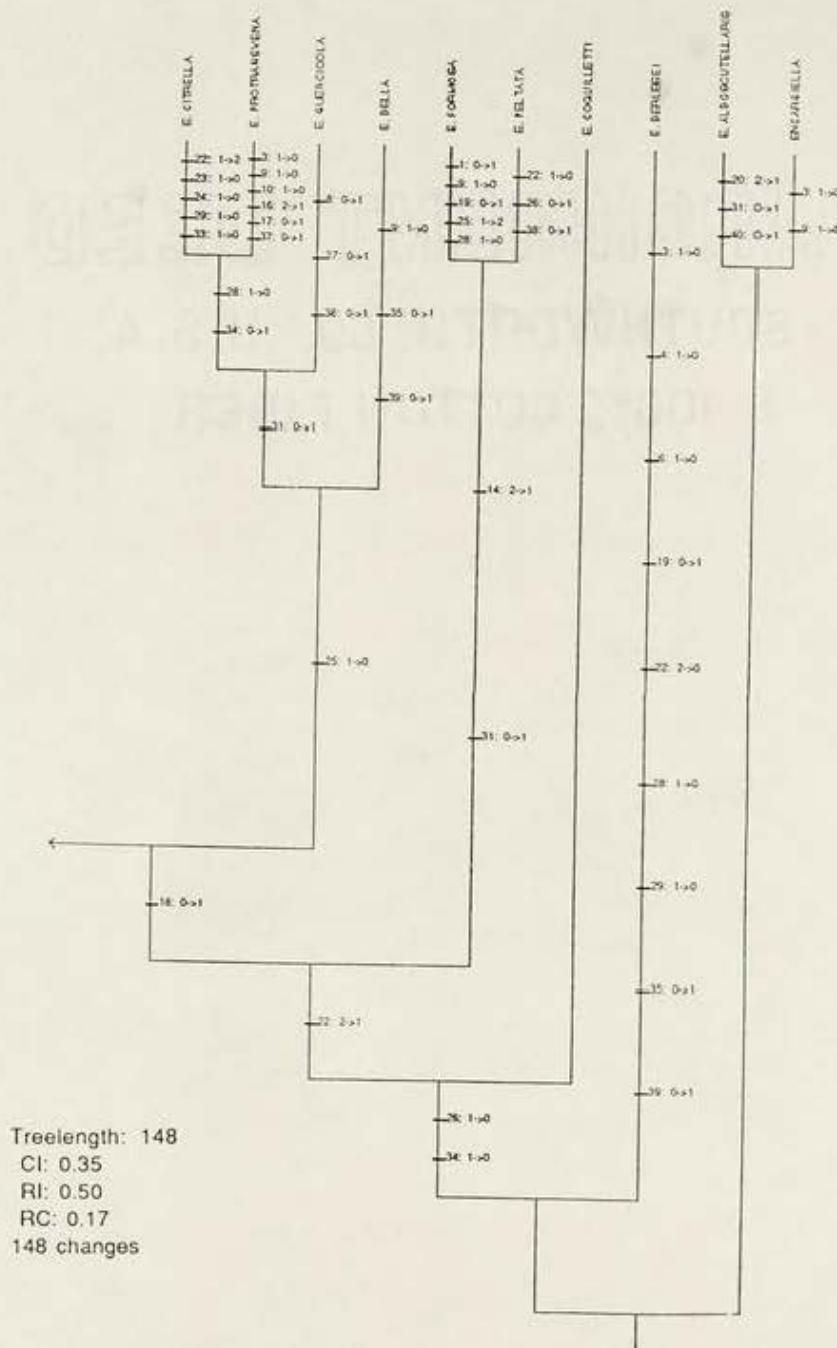


Figure 7.2. Cladogram of most parsimonious solution to data matrix (Part 1).

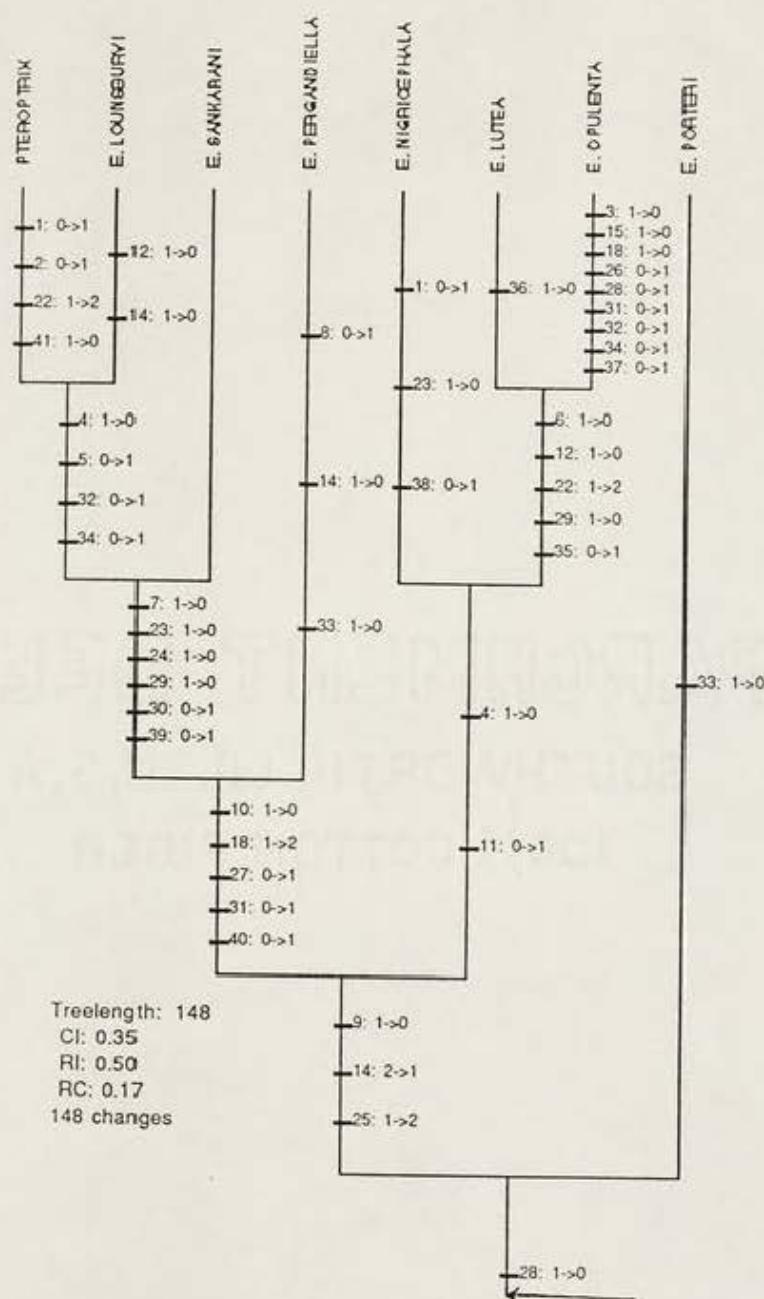


Figure 7.3. Cladogram of most parsimonious solution to data matrix (Part 2).

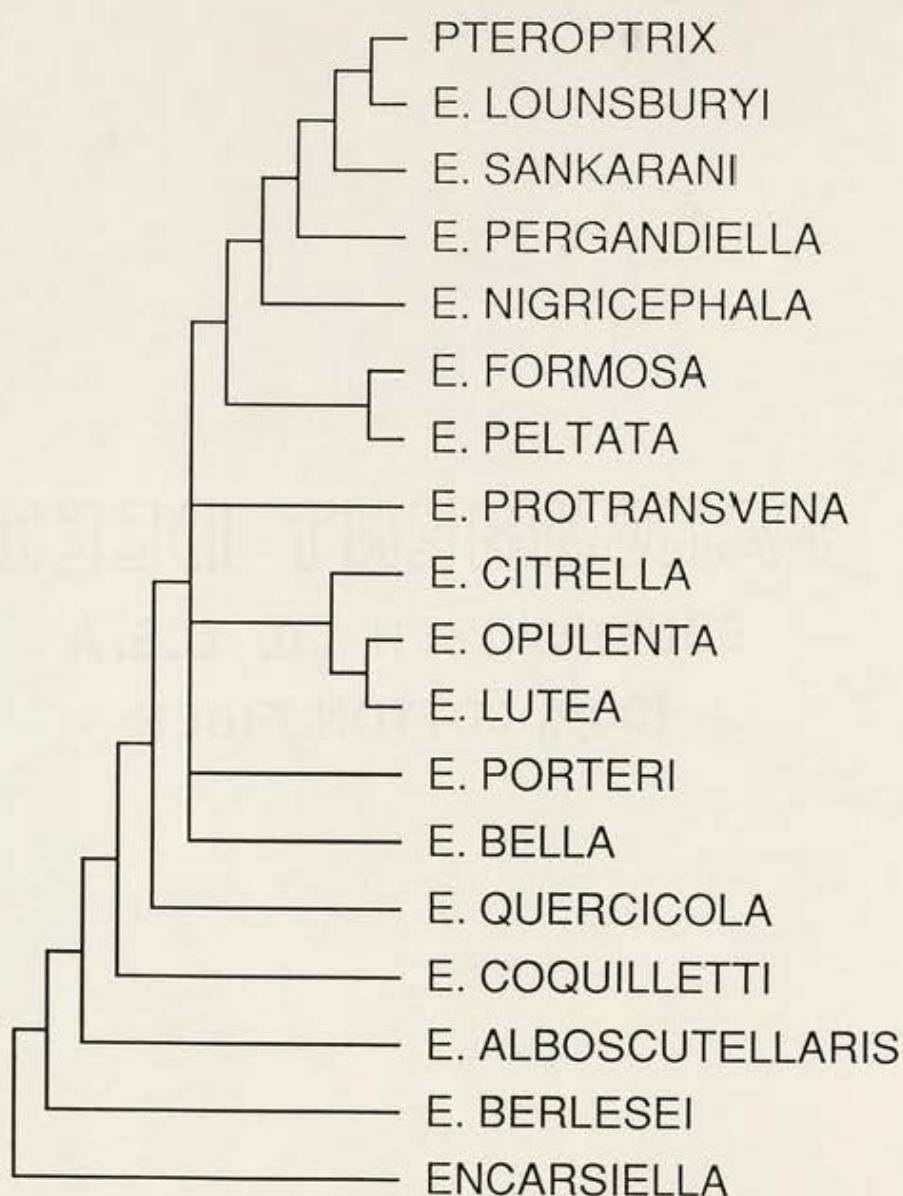


Figure 7.4. Strict consensus diagram of most parsimonious solution to data matrix.

CHAPTER 8

SURVEY OF NATURAL ENEMIES

8.1. Introduction

A statewide survey of the natural enemies of the SPWF was initiated in 1988 to gather information on the parasitoid complex of the SPWF in Florida and the humid neotropics, and to identify promising natural enemy species for eventual introduction into Florida and the southern United States. The objectives of the survey were to:

- 1) identify the species of parasitoids commonly found parasitizing SPWF.
- 2) measure the ratio between emergent SPWF and parasitoids as a comparative indicator of parasitism.
- 3) identify important SPWF wild host plant reservoirs.
- 4) identify changes in the parasitoid complex composition attributable to seasonal, geographic and host plant variation.
- 5) determine if SPWF and its parasitoids can overwinter in northern Florida
- 6) determine the host range for each of the parasitoid species reared from SPWF.

Prior to this survey, there were only three records of Encarsia parasitoids of the SPWF from the New World; E. hispida (= E. meritoria), E. tabacivora (= E.

pergandiella) and E. nigriceps. There were no records of SPWF parasitoids from Florida. A survey of the natural enemies of the SPWF of this magnitude has never been done in the New World. Gerling (1967) surveyed the natural enemies of Trialeurodes vaporariorum and Bemisia tabaci on cotton in California, but several of the parasitoid species reported were not identified to species and some were reared from other whitefly species.

Previous surveys of parasitoids of SPWF have been carried out in Pakistan by Dr. A. I. Mohyuddin of the International (formerly Commonwealth) Institute of Biological Control (IIBC), and in Africa and the Middle East by Dr. D. Gerling (University of Tel Aviv, Israel).

8.2. Methods

Samples of SPWF were collected from 111 different crop and weed species. Florida collections were made weekly, biweekly or monthly depending upon the time of the year and location. Collections were made primarily by Dr. Fred D. Bennett, Dr. David Schuster, Emily Vasquez and John Hogue of the University of Florida. In addition, Dr. Bennett made several collections of parasitized SPWF in many Caribbean and Latin American countries while traveling on other projects. Specimens were collected from 25 different counties in Florida with most of the collections centered around Gainesville, Bradenton, Immokalee, Homestead and several sites along the Florida Turnpike (Figure 4.1). The survey included parasitoids reared from SPWF from other states: California, Georgia, Louisiana,

Maryland, New York, South Carolina, Tennessee, Texas; and those reared from other countries: Mexico, Guatemala, Honduras, El Salvador, Costa Rica, Puerto Rico, Jamaica, Guadeloupe, Grenada, Venezuela, Colombia, Bolivia and Brazil. Extralimital specimens were reared from the SPWF and other hosts collected in China, Egypt, India, Hong Kong, Sudan and Thailand.

8.3. Results

Data presented of the relative abundance and seasonality of SPWF and its parasitoid species in different areas should be regarded as preliminary results because of the way in which the data were collected. They should be used only to indicate general trends in population and to indicate areas that may warrant more in-depth study.

8.3.1. SPWF Parasitoids

The distribution and relative abundance of 13 Encarsia species and 4 species from other genera that parasitize the SPWF in 12 countries of the New World are given in Table 8.1. Three new Encarsia species that attack SPWF are described herein. Eight Encarsia species and at least 2 Eretmocerus species were reared from SPWF in Florida. A new species of Amitus, discovered in Puerto Rico, was introduced into Florida in 1990. Release and recovery of the parasitoid were made in various locations throughout Florida (Figure 8.1).

The number of Eretmocerus species present in Florida and in the New World is not known at this time; the systematics of this genus is currently under review by Michael Rose, Texas A & M University. At least two species of Eretmocerus parasitize SPWF in Florida, one is similar to, if not the same as, Eretmocerus californicus Howard; the other, Eretmocerus mundus Mercet, was introduced into Florida in 1991 from Israel. The Metaphycus species reared from the SPWF from Venezuela is probably a new species and is the only bona fide record of this genus parasitizing an aleyrodid. Signiphora aleyrodis is a widely distributed but infrequently collected hyperparasitoid.

Encarsia pergandiella was the most common parasitoid species reared from SPWF in most countries surveyed, ranging from 20.1% of the parasitoid complex in Colombia to 80.3% in Puerto Rico. Overall, E. pergandiella, made up 40.9% of the parasitoids reared from New World countries (excluding the USA), and 50.6% of the Florida collections.

Encarsia nigricephala and Eretmocerus species were the next most common parasitoids. The relative abundance of E. nigricephala ranged from 1.1% of the SPWF parasitoid complex in Puerto Rico to 63.3% in Jamaica. However, the high relative abundance of E. nigricephala in the Jamaican collections may be due, in part, to the fact that several of the collections contained a mixture of both SPWF and banded-wing whitefly, Trialeurodes abutiloneus, an alternate host for this parasitoid species. Overall, E. nigricephala represents 15.6% of the parasitoid fauna of SPWF in the New World and about 13% of the Florida fauna. In

Gainesville, *E. nigriceps* is a seasonal parasitoid, high numbers of adults emerge during the early spring and fall, but is virtually absent during the summer months.

Eretmocerus represented 19.1% and 14.2% of the New World and Florida SPWF parasitoid fauna, respectively. In Gainesville, *Eretmocerus* is a seasonal parasitoid, its population is much higher during the fall months. Note that both males and females of this genus are primary parasitoids.

Encarsia meritaria, though described from Miami, Florida, was rarely collected in the Florida survey, but comprised a large proportion of the SPWF parasitoid complex in several countries (24% in Brazil and Venezuela, 13.3% in Jamaica and 9.6% in Puerto Rico).

Encarsia luteola comprised a large proportion of the SPWF parasitoid complex in southern Florida, but was only rarely collected in northern Florida. Similarly, *E. transvena* occurs much more frequently in southern Florida than in the northern region (Table 8.2).

The remaining *Encarsia* species occur rarely or sporadically. Large numbers of *Encarsia quaintancei* emerge during the early spring and late fall, but are rarely collected during the summer months. This species is more frequently reared from on *T. abutiloneus*, perhaps its preferred host.

Encarsia formosa is rarely reared from SPWF but is often reared from *Trialeurodes* species. The relative abundance of *Encarsia porteri*, *E. desantisi*, *E.*

Table 8.1. Distribution and relative abundance of parasitoids of *Bemisia tabaci* in the New World.

	Florida	Mexico	Guatemala	Honduras	Costa Rica	El Salvador	Puerto Rico	Jamaica	Guadeloupe	Venezuela	Colombia	Brazil	% x=7477 ¹
<i>Eretmocerus</i> sp.	14.2	50.0	6.0	17.8	8.2	Present	3.1	0	5.5	24.5	51.1	24.5	19.1
<i>E. pergandeiella</i>	50.7	28.3	73.8	28.5	30.9	Present	80.3	6.7	48.9	46.8	20.4	46.8	40.9
<i>E. nigricephala</i>	13.0	4.4	20.2	11.1	0	Present	1.1	63.3	23.5	4.1	20.4	4.1	15.6
<i>E. luteola</i>	14.4	4.2	0	Present	0	0	2.2	0	0	0.3	0	0.3	0.7
<i>E. transvena</i>	4.3	0.8	0	18.1	0	0	0	0	0	0	0	0	1.9
<i>E. quaintancei</i>	2.8	2.5	0	0	0	0	0	16.7	1.1	0.07	0	0	0.8
<i>E. formosae</i>	0.03	0	0	0	56.7	0	0	0	0	0	0	0	5.7
<i>E. meritoria</i>	0.1	0.3	0	4.7	0	0	9.6	13.3	4.9	24.0	6.1	24.0	9.8
<i>E. stramineus</i> group	0.4	0	0	0	0	0	1.3	0	0	0.03	0	0.03	0.1
<i>E. lutescens</i>	0	0	0	0	0	0	0	0	0	0	0	Present	-
<i>E. porteri</i>	0	0	0	3.2	0	0	0	0	0	0	0	Present	0.3
<i>E. desandisi</i>	0	0	0	0	0	0	0	0	0	Present	0	Present	0.01
<i>E. polaszekii</i>	0	0	0	0	0	0	0	0	0	0	0	Present	-
<i>E. lanceolata</i>	0	0	0	0	0	0	Present	0	0	0	0	0	-
<i>E. pseudocitrella</i>	Present	0	0	0	0	0	0	0	0	0	0	Present	-
<i>Encarsia</i> sp.	0.4	2.5	0	0	15.7	0	0	0	0	0	0	0	1.8
<i>Amitus</i> sp.	0.1	0	0	0	1.5	0	1.1	0	0	0	0	0	0.26
<i>Sigmothrips</i> sp.	0.17	0	0	0.8	2.7	0	1.1	0	12.1	0	2.0	0	1.8
<i>Metaphycus</i> sp.	0	0	0	0	0	0	0	0	0	Present	0	0	-
No. Parasitoids	41,072	135	42	235	178	10	1184	35	210	4742	47	679	48,559

¹ Total number and percentages for all countries, excluding Florida records

Table 8.2. Distribution and relative abundance of parasitoids of *Bemisia tabaci* in Florida.

	Bradenton	Cane Creek	Fort Pierce	Gainesville	Home-stead	Immokalee	Fl. Keys	Leesburg	Miami	Oka-humpka	Pompano Beach	Sanford	Turkey Lake	Snapper Creek	West Palm Beach	% Tot
<i>Eretmocerus</i>	14.5	7.7	263	15.7	8.7	1.7	1.9	45.4	18.7	1.8	5.9	15.9	6.3	13.9	25.1	14.17
<i>E. pergandeiella</i>	62.1	49.3	46.6	51.8	85.3	72.1	3.3	49.4	51.1	58.3	21.5	48.0	47.1	44.8	69.2	50.66
<i>E. nigriccephala</i>	22.6	25.1	11.9	28.4	3.3	25.3	1.9	3.3	8.4	17.3	0.7	35.7	6.3	2.2	2.2	12.97
<i>E. luteola</i>	0.2	14.9	0	1.1	2.4	0.4	62.0	0.0	5.0	21.9	59.2	0.355	10.3	37.4	0	14.40
<i>E. transvena</i>	0.4	0	5.6	0	0	0.3	26.0	0	12.1	0	11.9	0	0	1.3	2.8	4.29
<i>E. qualinacei</i>	0.1	2.0	6.3	0.1	0.07	0	0	0	1.0	0	0.6	0	30.0	3	0.4	2.75
<i>E. formosa</i>	0	0	0.4	0.04	0	0	0	0	0	0	0	0	0	0	0	0.03
<i>E. meritoria</i>	0	0	0.1	0	0	0	2.0	0	0	0	0	0.05	0	0	0	0.14
<i>Encarsia strenua</i> gr	0	0	0	2.5	0	0	0	0	3.2	0	0	0	0	0	0	0.40
<i>E. pseudocircella</i>	0	0	0	Present	0	0	0	0	0	0	0	0	0	0	0	..
<i>Encarsia</i> sp	0	0.0	0.0	0.3	0.03	0	0.7	0	0.3	0.7	0.2	0	0	0.1	0	0.25
<i>Sigmothrips</i> sp	0	0	0	0.03	0	0.1	2.2	0	0.2	0	0	0	0	0	0	0.17
<i>Amitus</i> sp	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
No. Parasitoids	10,116	442	1843	14,348	2648	2364	383	330	1573	356	1334	2241	1240	987	867	41,072

lutea, *E. polaszeki* and *E. lanceolata* is not known since all of these species were collected opportunistically in other countries. For example, *E. polaszeki* was reared in large numbers from SPWF in one location in Brazil. Whether this parasitoid plays a major role in controlling the SPWF in the area or whether it was collected at the time and place where it was most abundant, is not known, but merits further study.

8.3.2. Alternate Hosts of SPWF parasitoids

Records of alternate whitefly hosts for SPWF parasitoids are given in Table 8.3. Several Encarsia species have very wide host ranges while others such as *E.*

Table 8.3. Alternate host of SPWF Encarsia parasitoids.

	Aleurodicus cocois	Aleurodicus dispersus	Aleuroglandulus malangae	Aleuroplatus coronata	Aleuroplatus ilicis	Aleurothrixus floccosus	Aleurotachellus trachoides	Crenidorsum sp.	Dialeurodes citri	Dialeurodes chiloili	Dialeurodes kirkaldyi	Trialeurodes acaciae	Trialeurodes abutiloneus	Trialeurodes floridensis	Trialeurodes packardi	Trialeurodes vaporariorum	Trialeurodes variabilis
<i>E. citrella</i>			•					•									
<i>E. desantisi</i>																•	•
<i>E. formosa</i>		•		•		•		•	•	•					•	•	•
<i>E. luteola</i>	-				•												
<i>E. meritaria</i>		•															
<i>E. nigricephalia</i>						•											
<i>E. pergandeiella</i>		•	•	•	•	•	•		•	•	•				•	•	•
<i>E. porteri</i>																	
<i>E. strenua</i> gr	•		•	•					•	•	•			•		•	•
<i>E. quaintancei</i>																	

guaintacei and E. desantisi have relatively narrow host ranges. The distinction needs to be made between a preferred host and an acceptable host. Both E. pergandiella and E. formosa are rarely reared from Dialeurodes species, but each is prevalent on other whitefly species.

8.3.3. Population Dynamics of SPWF and Parasitoids

The following four sites were selected as representative of different geographical regions of Florida for analysis of the population dynamics of SPWF and its parasitoids: Gainesville - northcentral region of Florida; Bradenton - west central region; Immokalee - southwest coastal region; and Homestead - southeast costal region of Florida. Data were collected from the fall of 1988 to the fall of 1992. For some sites, data are presented only for 1990 and/or 1991, since more collections were made and in a more systematic manner during that period of time.

Unless otherwise indicated, the data are presented on the average number of SPWF and parasitoid adults reared per sample of infested plant leaves per month. This measure may be bias in some cases, due to the high degree of variability in the number of individuals reared on certain host plants and at certain times of the year. For example, the overall number of SPWF adults reared from Gainesville in September of 1990 was more than four times that of October of 1990; whereas the average number of SPWF adults per sample in September was only slightly higher than that of October. Data are presented of the average number of individuals and the total number of individuals reared in Gainesville.

8.3.3.1. Gainesville

8.3.3.1.1. SPWF population

Data were recorded from September of 1988 through December of 1992. The SPWF population was highest in September, then declined in October and November, and remained at very low levels during the winter months (Figure 8.2a). The high SPWF population in September and October coincided with the maturation of Glycine max, Desmodium tortuosum and Euphorbia heterophylla and other host plants that harbor large numbers of the SPWF. The dynamics of the SPWF population in 1989 was similar to that of the previous year. The number of adults per sample peaked in October. However, the total number of SPWF individuals reared per month in September was twice as much as that of October in both 1988 and 1989, and the population in October and November showed little change (Figure 8.8). Percent parasitization increased in November of 1988 and February, September and November of 1989, usually associated with decreases or low populations of the SPWF.

The mean number of SPWF adults per sample was much higher in 1990 than in 1989 (Figure 8.2b). There were large increases in the SPWF population in February, May, July and September. The large increase in the SPWF population that occurred in February of 1990 was halted by a frost that occurred in late February. The difference in the number of individuals reared in 1990 versus that of previous years may be due to the larger number of samples taken in 1990, differences in environmental conditions, and/or the fact that more samples were

taken from Brassica and other hosts which harbor large number of parasitoids that were not sampled from in the previous years. Total numbers of SPWF adults were highest in July and October (Figure 8.9). Parasitization showed increases in March, April, June, October and the months that followed.

In 1991, as in the previous year, there were large increases in the SPWF population in May, July and October; but the overall level of the SPWF population was lower than it was in 1990 (Figure 8.2c). The differences in population level may be due to a combination of environmental conditions and the greater role the parasitoid complex played in 1991. Unlike in 1990, the SPWF population was relatively low during the winter and early spring months, not much greater than that of the parasitoid complex. The level of parasitization was higher in 1991, reaching 75% in March. There was not a large increase in the SPWF in June followed by a very large population in July as in 1990. Parasitization in August was about 40% while in August of 1990, it was only about half as much. The data indicate the importance of controlling the SPWF population in the early stages of its development.

Data for 1992 were based on fewer collections but indicate that both the SPWF and parasitoid populations were relatively low until August, then declined in September, and were very low in October and December (Figure 8.4). Parasitization increased in September due mostly to the large decrease in the SPWF population.

8.3.3.1.2. Parasitoid Population Dynamics

The dynamics of the parasitoid population were similar for 1988 and 1989; both the mean and total number of parasitoids reared in September, October and November were relatively equal (Figure 8.2a). The population declined sharply in December due to unfavorable environmental conditions and the decrease in the SPWF population with the deterioration of its host plants. In most cases, changes in the parasitoid population were coordinated with those of the SPWF population; when the SPWF population was high, the parasitoid population was high, and visa-versa. The parasitoid population did not respond effectively to the large increase in the SPWF population that occurred in June of 1989, and by July the SPWF population was at outbreak proportions.

The parasitoid population was low during the winter and spring of 1990 (Figure 8.2b). Increases in the population occurred in March, May, June and October, following somewhat that of the SPWF. The large increase in the SPWF in May was not reciprocated by an equal increase in the parasitoid population, and the large increase in the SPWF population in July was met by actually a decrease in the parasitoid complex from its June level. The total number of parasitoids actually increased slightly during July, but still well below the number of SPWF (Figure 8.9). The parasitoid population continued to decline during the summer months until October. There were increases in the percent parasitization in March, June and October and in April, November and December when the SPWF population was low.

In 1991, the parasitoid population was greater than and the SPWF population was less than in the previous year (Figure 8.2c). Percent parasitization was much higher during the first five months of 1991 than it was in 1990. Increases in the parasitoid population occurred in March, May, July and November. Unlike in 1990, percent parasitization increased from June until August and only declined slightly in September; the difference is probably largely due to the lower SPWF in 1991. Total parasitoids reared in 1991 gradually increased from May until July, declined in August, then gradually increased until November (Figure 8.9). In 1992, the parasitoid population was very low until August, declined slightly in September, then decreased dramatically in October.

8.3.3.1.3. Parasitoid Complex

Three parasitoid species, Encarsia pergandiella, E. nigriceps and Eretmocerus sp., comprise about 98.5% of the parasitoids reared from SPWF in Gainesville. E. pergandiella is the most dominant species present during most months of the year. E. nigriceps and Eretmocerus emerge primarily from July to December (Figure 8.3a,b,c), and are usually more predominant than E. pergandiella in September and October. The composition of the parasitoid complex was similar for the fall of 1988 and 1989; E. nigriceps was most the most prominent species in September, E. pergandiella the most prominent in October and November, and the Eretmocerus population greatest in October (Figure 8.3a).

Besides the overall increase in the number of parasitoids reared in 1990, there were also differences in the parasitoid complex (Figure 8.3b). Eretmocerus was the most predominant species in September and October, and E. nigricephala the most predominant species in November.

Encarsia nigricephala showed a greater presence in the first five months of 1991 than it had done in previous years (Figure 8.3c). Interestingly, there were more parasitoids reared during this period in 1991, while the SPWF population was at a lower level than in 1990, when there was a greater number of hosts available. The relative abundance of E. nigricephala was much higher in July and August 1991 than it had been in the previous years, and by September, it and Eretmocerus, comprised almost the entire SPWF parasitoid fauna. The parasitoid complex in 1992 differed from that of previous years by the greater presence of E. transvena in August and September (Figure 8.5).

Hyperparasitism by Encarsia pergandiella males was not considered to be a major factor limiting the populations of the other two parasitoid species. Increases in the E. pergandiella population usually followed shortly after increases in the SPWF population and not increases in the number of E. nigricephala and Eretmocerus individuals.

8.3.3.1.4. Parasitoid Sex Ratio

Data of the sex ratio for the three major SPWF parasitoids in Gainesville are present in Figure 8.6. E. nigricephala is a very female-biased species; its sex ratio

is usually between 85 and 95% female for most of the year. Males are often common in collections made in January and February. Later, there are small numbers that emerge in April, May or June and November. Other than the early months, when the population is very low, the relative abundance of males is greatest in August.

The sex ratio of E. pergandiella is much more variable than the other parasitoid species and averages about 60% female over the year. A higher percent of males emerged in September of 1988 and June and September of 1989. The sharp increase in the percent female of E. pergandiella in October 1988, and August and October of 1989, coincided with an increase in the SPWF population and a decrease in the percent female E. nigriceps. Similarly, increases in the percent female E. pergandiella in June, August and October of 1990 and March of 1991, coincided with decreases in the percent female E. nigriceps.

The sex ratio of Eretmocerus usually ranges between 55 and 65 percent female; data presented of its sex ratio from January to June is based on a very small number of individuals, and should probably be disregarded. The female to male ratio is least in August and September and becomes more female bias in October and November (Figure 8.7).

8.3.3.1.5. Host-Plant Relationships

8.3.3.1.5.1. SPWF Seasonality

The relative abundance of SPWF in an area is dependent upon the

availability and suitability of the host plants. The total number of SPWF adults reared from various host plants in Gainesville for 1990 and 1991 is given in Figures 8.10. The SPWF population is very low from January to April, developing primarily on Emilia, Lepidium, Sonchus and other early season weed species, as well as Brassica. Large numbers of SPWF are reared from Brassica starting in May, and increase until July. SPWF begin to emerge from Sesamum and other host plants in July and increase until October. Glycine, Euphorbia and Desmodium are other important host from which the SPWF emerges in the fall.

8.3.3.1.5.2. Parasitoid Seasonality

By and large, parasitoids emerge in relative proportions from the same host plants as the SPWF. Early in the year, they emerged from Brassica, Lepidium and Euphorbia, on which they probably overwinter. During the summer months, they emerge primarily from SPWF on Brassica and Sesamum (Figure 8.11). Many parasitoid emerged in the fall from Glycine and Desmodium.

8.3.3.1.5.3. Parasitoid complex

The relative abundance of each parasitoid species on different host plants, and for different years on the same host plant, is often highly variable. Perhaps some of the differences can be explained by the time of the year at which the host plant is available. The parasitoid complex of SPWF reared from host plants such as Emilia, Lepidium and Sonchus is composed primarily of E. pergandiella (Table

8.4). These plants are important hosts during the winter and spring, when *E. pergandiella* is, by far, the most prevalent parasitoid. Similarly, the parasitoid complex on Glycine and Desmodium, which mature in the fall, have a higher percentage of Eretmocerus and *E. nigriceps*. It is not known whether the greater incidence of *E. pergandiella* during the winter and spring is due to better adaption to the cooler temperatures, or to preference for the host plants available at that time, or to hyperparasitism by *E. pergandiella* males, or some unknown factor.

Leaf texture, leaf hairiness, or leaf exudates may effect the composition of the parasitoid complex on the plant. Eretmocerus was rarely reared from SPWF on Sonchus, tomato (Lycopersicon esculentum), Sida, okra (Abelmoschus esculentum), and cucumber (Cucumis pepo), all which have dense hairy leaves. The glandular secretions on the leaf hairs of tomato may further inhibit parasitoid movement.

E. nigriceps often made-up a large proportion of the parasitoid complex on hairy-leaf plants; for example, cucumber, Cassia, okra, watermelon (Citrullus lanatus). However, it also made-up a large proportion of smooth-leaf plants such as Chamaesyce, Euphorbia, and Solanum. In Gainesville, *E. luteola* was reared predominantly from SPWF on Euphorbia heterophylla, although in other sites it was reared from a wider variety of plants. *E. pergandiella* comprised a major portion of the parasitoid complex of almost all host plants surveyed, apparently little effected by leaf characteristics.

Table 8.4. Relative abundance and percent female of parasitoid species reared from SPWF on various plant species in Gainesville, Florida.

Plant	% parasitidae	% total	% female	nigrocephala	% total	% female	Encyrtocerus	% total	% female	other	% Total	Total
Anthospermum	22	34.4%	69.2	40	62.5%	60.7	2	3.1%	50.0	0	0.0%	64.0
Alyssum	28	20.6%	84.0	5	5.9%	60.0	54	63.5%	46.1	0	0.0%	85.0
Bidens	22	7.7%	69.8	208	73.0%	65.0	7	2.5%	42.9	49	10.0%	285.0
Bressia	2448	70.6%	56.3	709	22.2%	84.6	10	0.3%	50.0	27	0.8%	3104.0
Cassia	154	33.0%	69.5	149	32.0%	71.1	163	35.0%	45.8	0	0.0%	466.0
Chamissoya	408	51.2%	69.4	207	38.5%	85.2	81	10.2%	74.1	1	0.1%	787.0
Cucurbita	113	40.4%	78.6	137	48.8%	9.8	24	8.8%	58.3	8	2.1%	282.0
Dioscorea	425	40.8%	63.2	255	28.7%	81.8	223	24.5%	54.1	0	0.7%	803.0
Emilia	144	69.0%	81.3	55	28.7%	89.4	1	0.5%	100.0	8	2.9%	255.0
Euphorbia	101	21.6%	52.0	545	61.5%	80.0	17	1.8%	58.8	123	15.0%	888.0
Glycine	765	41.1%	71.5	422	21.6%	88.4	693	37.2%	58.3	1	0.1%	1881.0
Hibiscus	881	85.4%	59.3	4	0.5%	100.0	100	13.1%	54.3	0	0.0%	785.0
Indigofera	88	65.5%	81.5	50	31.4%	88.7	21	13.2%	80.0	0	0.0%	153.0
Lantana	150	89.8%	82.9	3	1.8%	100.0	2	1.3%	50.0	0	0.0%	155.0
Lepidium	117	32.6%	71.4	1	0.8%	100.0	2	5.6%	48.0	1	0.8%	125.0
Lycopersicum	209	73.0%	54.1	70	24.7%	80.0	4	1.4%	75.0	0	0.0%	283.0
Richardia	18	14.4%	77.0	28	22.4%	82.1	79	63.2%	49.4	0	0.0%	125.0
Sesamum	625	30.0%	82.6	1010	48.5%	88.5	447	21.5%	50.0	0	0.0%	2192.0
Sonchus	315	97.5%	60.1	6	1.0%	50.0	2	0.6%	50.0	0	0.0%	223.0
Mean	363	52.7	67.0	209.7	29.1	80.5	101.0	16.2	56.7	12.1	2.1	680.0
Stand Err	127	8.6	2.1	64.0	5.1	3.2	41.4	4.8	3.1	7.3	1.1	19.7
Median	154	46.8	69.2	70.0	26.7	88.4	21.0	0.6	50.0	0.0	0.0	285.0
Stand Dev	554	28.4	9.1	278.1	22.1	13.0	180.5	20.2	13.5	31.7	5.0	835.4
Variance	207142	8.1	82.8	27912.9	4.8	192.1	32593.1	4.1	181.6	1004.1	0.2	68706.2
Minimum	18	7.7	52.0	1.0	0.5	50.0	1.0	0.3	42.8	0.0	0.0	64.0
Maximum	2448	97.5	84.0	1010.0	23.0	100.0	893.0	63.5	100.0	133.0	16.8	2194.0

The parasitoid complex may differ for the same host plant at different locations. *E. nigriceps* comprised about 25% of the parasitoid complex on tomatoes in Gainesville, but only about 5% of the complex in Bradenton. *E. nigriceps* and *Eretmocerus* comprised about 55% and 5%, respectively, of the parasitoids reared from SPWF on *Euphorbia heterophylla* in Gainesville, but about 10 and 45%, respectively, of those reared from the same host in Bradenton.

The reasons for many of the differences in the parasitoid complex on different plants remain unexplained. *E. nigriceps* comprises a large proportion of the parasitoids reared from SPWF on *Euphorbia* and *Chamaesyce*, but a very small proportion of that of *Hibiscus* and *Brassica*, all which are smooth-leaf plants. Certain allelochemicals in the host plant may inhibit certain parasitoid species.

The parasitoid complex may be different from one year to the next. *E. nigriceps* was present in relatively high numbers on *Brassica* in 1990, but was virtually absent during the summer of 1991, on the same crop and at the same location (Figure 8.13).

8.3.3.1.6. Host Plant Examples

8.3.3.1.6.1. Brassica oleracea acephala

SPWF emerged in high numbers from *Brassica* in May and August of 1990 (Figure 8.12). The parasitoid population peaked in June and declined until November, and failed to respond effectively to the large number of SPWF in August. Parasitism ranged from 20 to 40% for most of the year, except in

November when a large number of parasitoids emerged.

Overall levels of SPWF and parasitoids population were lower in 1991 than in 1990. The SPWF population was highest in May and remained stable through July. The parasitoid population remained stable at a relatively low level, except in Jan when a large number of E. pergandiella females emerged. Percent parasitism was above 50% from January to April and in November, and dropped below 50% from May to July, when the SPWF population was high.

The parasitoid complex was composed almost entirely by E. pergandiella and E. nigricephala (Figure 8.13). In 1990, E. nigricephala made-up a large proportion of the parasitoid complex from July until December, but was almost absent in 1991.

8.3.3.1.6.2. Chamaesyce hyssopifolia

SPWF emerged in large numbers in October of 1988 and September of 1989 in Gainesville (Figure 8.14a). The parasitoid population remained at a relatively low level throughout the year. The SPWF emerged in large number in August and September of 1990 and in July of 1991 (Figure 8.14b). The parasitoid population was well below the SPWF population for these months.

The parasitoid composition was dominated by E. pergandiella through much of the year. E. nigricephala and Eretmocerus were much more prominent in September and October than in the other months.

8.3.4. Other Florida Sites

The dynamics of the SPWF population in the other Florida sites for 1990 and 1991 are given in Figures 8.18-8.22. In general, the seasonal trend of the SPWF and parasitoid populations differed from that of Gainesville in that the populations began increasing earlier in the season.

8.3.4.1. Bradenton

The SPWF population in Bradenton was very low from February to April of 1990 and began increasing in May (Figure 8.18a). There was a large increase in the population in June, the magnitude of this increase was even greater if the total number of SPWF reared were considered (Figure 8.18b). The population level was much higher than has been recorded in Gainesville. The SPWF population decreased in July. The average number of SPWF per sample increased greatly in August, but the total number that emerged actually decreased slightly from the July level. Percent parasitization increased from May to August.

The SPWF population was at a higher level in May of 1991 than it had been in May of 1990, but there was not a significant increase in the population in June. In Bradenton, the population peaked in May or June; in Gainesville it peaked in July.

The parasitoid population was very low in May, increased slightly in June, decreased in July and showed an enormous increase in August. Percent parasitism was high in February and April of 1990 when the SPWF population was

very low, dropped to about 15% when the SPWF population began to increase in May, and increased steadily until August.

The parasitoid composition was largely dominated by *E. pergandiella* until August of 1990, when large numbers of adult *E. nigriccephala* and *Eretmocerus* emerged (Figure 8.19). *Encarsia luteola* was primarily present in February and July and comprised a greater proportion of the parasitoid complex than it did in Gainesville.

8.3.4.2. Homestead

The SPWF population was very high in May of 1990 in Homestead and declined sharply in June and July (Figure 8.20). The population was very low in August and September and increased slightly in November.

The parasitoid complex increased steadily from February to July, declined in August and September, and showed a greater increase than did the SPWF in November. It is doubtful that the great decline in the SPWF population in August was the result of parasitoid activity, since the parasitoid population was low. The decline may have coincided with the harvest of collards and other host plants from which collections were made. The SPWF population increased in November of 1990 but the parasitoid population increased even greater. The SPWF population peaked in June of 1991, as did the parasitoid population.

E. pergandiella was the most common species and *E. nigriccephala* and *E.*

luteola were especially prominent in November of 1990 and in October of 1991 (Figure 8.21). Unlike in Gainesville, *Eretmocerus* was reared throughout the year.

8.3.4.3. Immokalee

Collections of SPWF and its parasitoids were made primarily on okra, *Abelmoschus esculentum* and collards, *Brassica oleracea acephala*. A large number of SPWF adults emerged in February of 1990 in Immokalee (Figure 8.22). The population declined in March and April, increased in May and June, then decreased in July and August. The parasitoid population remained relatively low and stable until May, when it increased with the increase in the SPWF.

The parasitoid complex was comprised largely of the same three parasitoids. *E. pergandiella*, by far, was the most dominant species from February to May (Figure 8.23). As in Bradenton, the population of *E. nigriceps* and *Eretmocerus* emerged in large numbers in June, which is at least a month earlier than they emerged in the Gainesville area. *Eretmocerus* individuals were only reared in June.

8.3.5. Discussion

The relatively low SPWF population between January and April in Florida is probably due a combination of factors. During the first two or three months of the year, climatic conditions and unavailability of adequate host plant material probably play a large role in suppressing the SPWF population. Parasitoids are

present at relatively low numbers, but because the SPWF is also present in low numbers, the overall rate of parasitism is high, reaching 60% or more.

The population of SPWF increases dramatically between May and June and sometimes into the following month. There is often a delay in the response in parasitoid population to the increase in SPWF population due to asynchronization in their life cycles. The emergent SPWF females need to oviposit, the eggs need to develop, and the nymphs need to develop until the 2nd or 3rd instar before they are suitable for oviposition for most of the parasitoid species. Most parasitoid species require between 12 and 25 days to develop.

As the SPWF population increases and a large percentage of primary host become available, the parasitoid population increases and the relative proportion of females (primary parasitoids) increases. The decline in the SPWF population during the summer months can not be fully attributed to the slight increase in the parasitoid population or the decrease in hyperparasitism by Encarsia males. In part, it may indicate the passing of another SPWF generation or may be associated with the physiological condition of the host plants or host feeding by parasitoid adults on the SPWF nymphs.

The sharp increase in the SPWF population in September and October may be due to the emergence of another SPWF generation, in addition to a wide array of available host plants reaching maturity along with favorable climatic conditions. Host plants, such as sesame and soybeans, that mature in October harbor large numbers of SPWF. The decline in the SPWF population in November is largely due to the climatic conditions and unavailability of suitable host plants.

The overall sex ratio for *E. pergandiella* averages about 62% female, however, it is not constant during the entire year. Large numbers of female emerged in October 1989, June and November 1990, and May, June, July and November of 1991. In almost all cases, the higher percentages of female parasitoids followed high SPWF populations in the previous month. The findings coincide with those found by Hunter (1989), who found that *E. pergandiella* females layed a higher proportion of female eggs when the proportion of available unparasitized whiteflies was high.

The overall sex ratio of *E. nigricephala* in Gainesville averaged about 87% female. Large numbers of females usually emerged in September (sometimes in October). Males are found in low numbers throughout most of the year, with most emerging in large numbers in August. The large numbers of males emerging during the early and latter part of the year (e.g. February and November) is not uncommon, and may be the result of superparasitism by the females confronted with a scarcity of whitefly hosts and mates.

The overall effect of the parasitoids on the SPWF population in the area or on certain host plants is not only affected by the number of SPWF and parasitoids, but also by the composition of the parasitoid complex. Both female and male *Eretmocerus* develop as primary parasitoids of the SPWF. Males are extremely rare of the *Amitus* species recently introduced into Florida. *Encarsia strenua* and *E. formosa* are, by large, thelytokous. For most of the *Encarsia* species that have been studied, the males develop as hyperparasitoids on primary parasitoids inside the SPWF. The sex ratio differs for several of the *Encarsia* species that parasitize

the SPWF. The sex ratio of E. pergandiella averages about 60% female, while that of E. nigricepsala is about 85-95% female. Therefore, given the same number of E. pergandiella and E. nigricepsala individuals, the latter would probably have a greater effect on the SPWF population.



Figure 8.1. Release and recovery sites of Amitus sp. introduced in Florida.

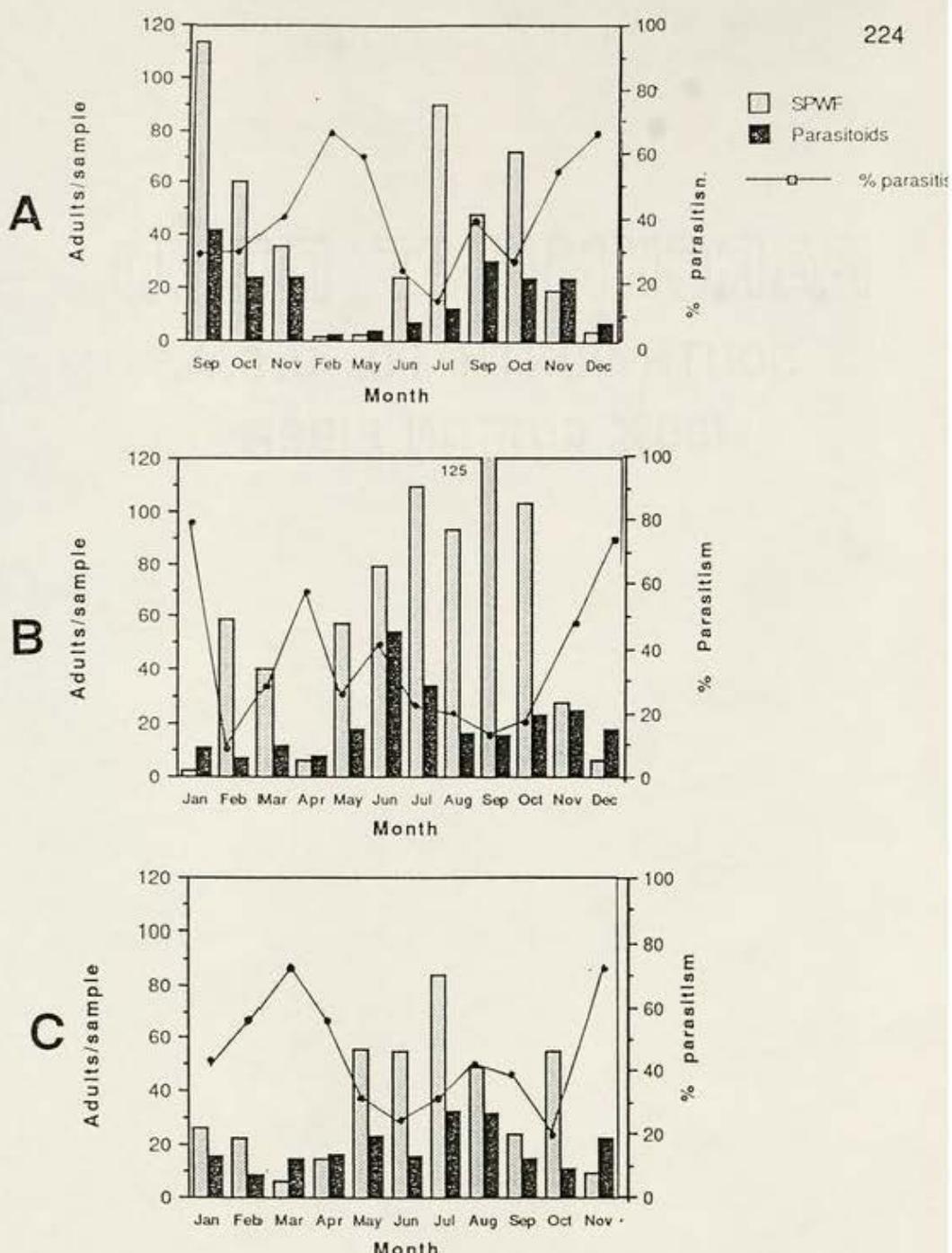


Figure 8.2. SPWF and parasitoids (mean/sample) reared from wild and cultivated hosts and % parasitism. Gainesville a) 1988-1989 b) 1990 c) 1991.

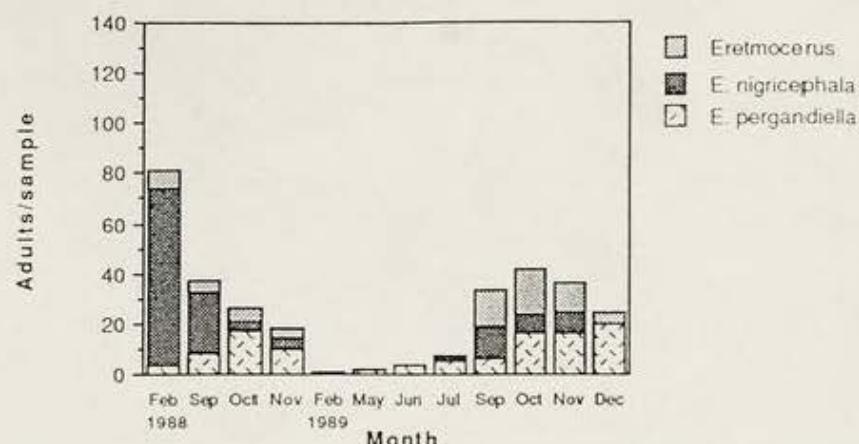
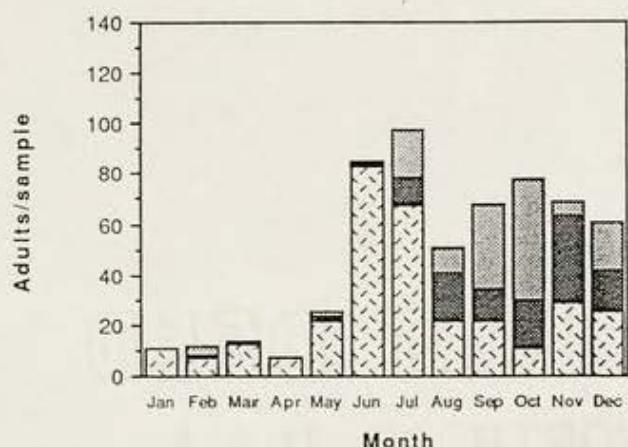
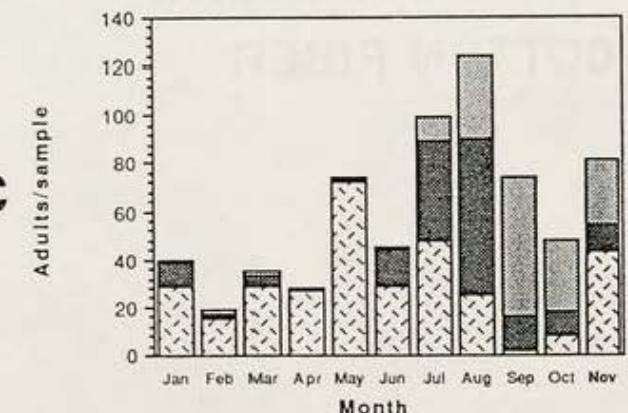
A**B****C**

Figure 8.3. Parasitoid species (mean/sample) reared from SPWF on wild and cultivated hosts: Gainesville. a) 1988-1989 b) 1990 c) 1991.

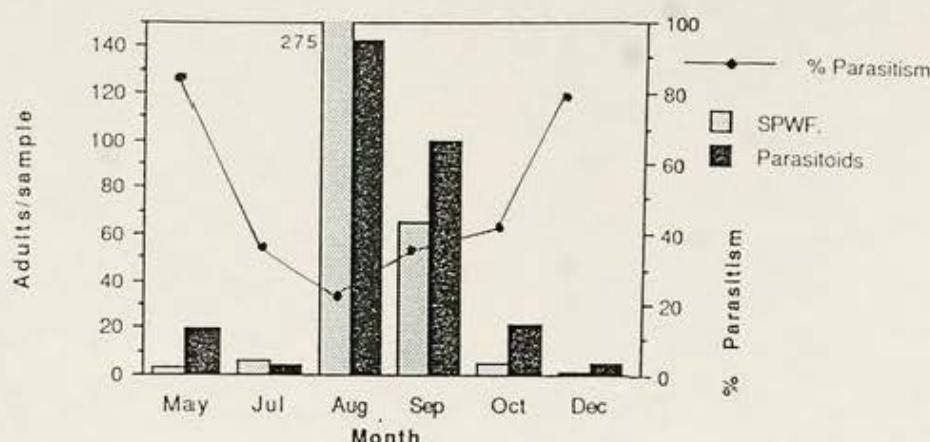


Figure 8.4. SPWF and parasitoids (mean/sample) reared from wild and cultivated hosts and % parasitism. Gainesville 1992.

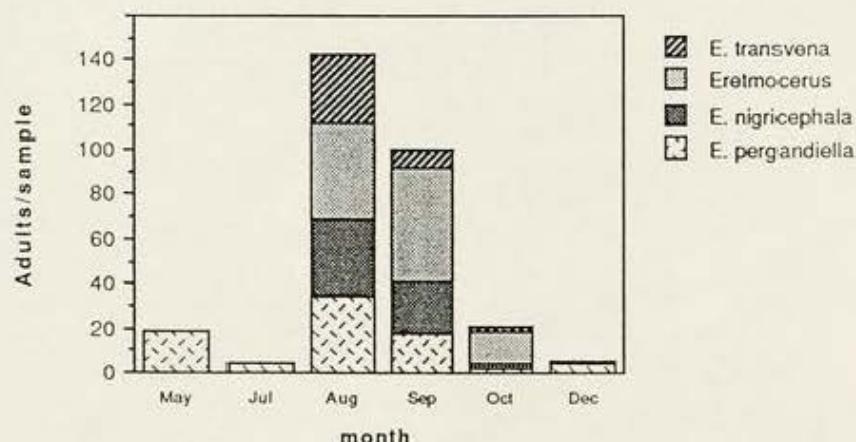


Figure 8.5. Parasitoid species (mean/sample) reared from SPWF on wild and cultivated hosts: Gainesville 1992.

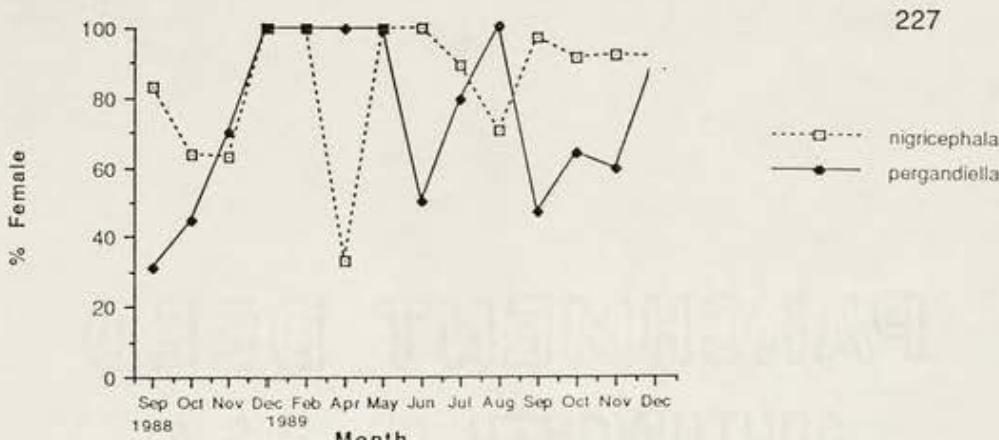
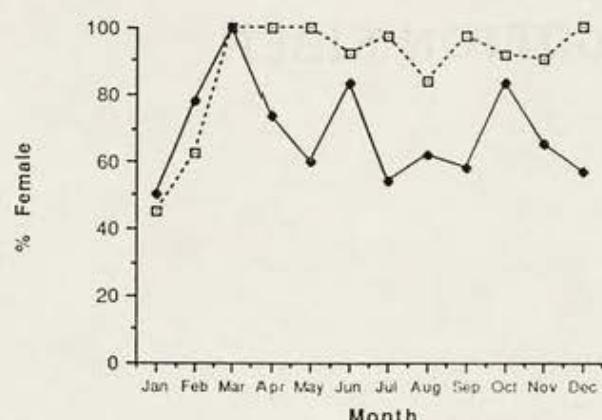
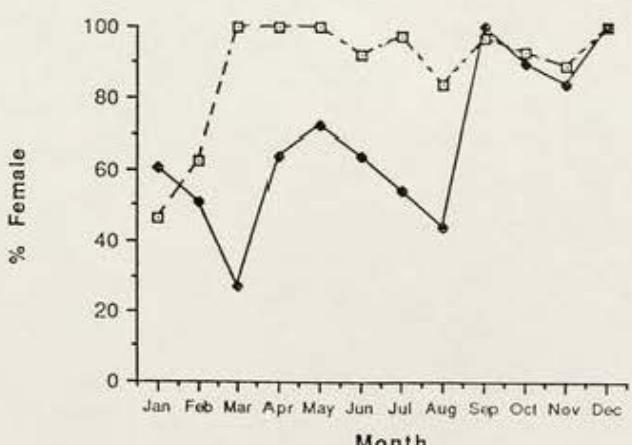
A**B****C**

Figure 8.6. Seasonal variation in sex ratio of *E. pergandiella* and *E. nigriceps*, in Gainesville. a) 1988-1989 b) 1990 c) 1991.

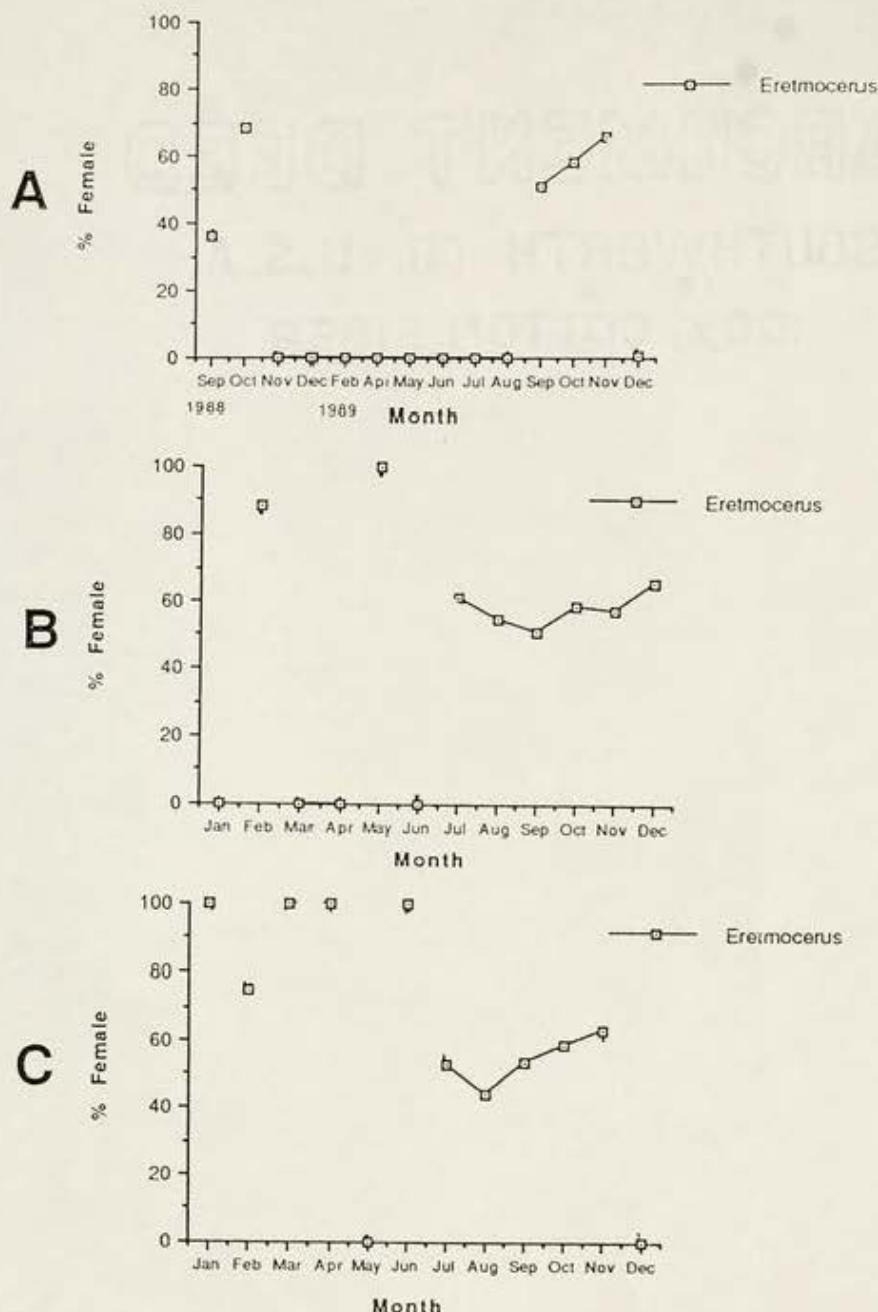


Figure 8.7. Seasonal variation in sex ratio of *Eretmocerus* in Gainesville.
a) 1988-1989 b) 1990 c) 1991.

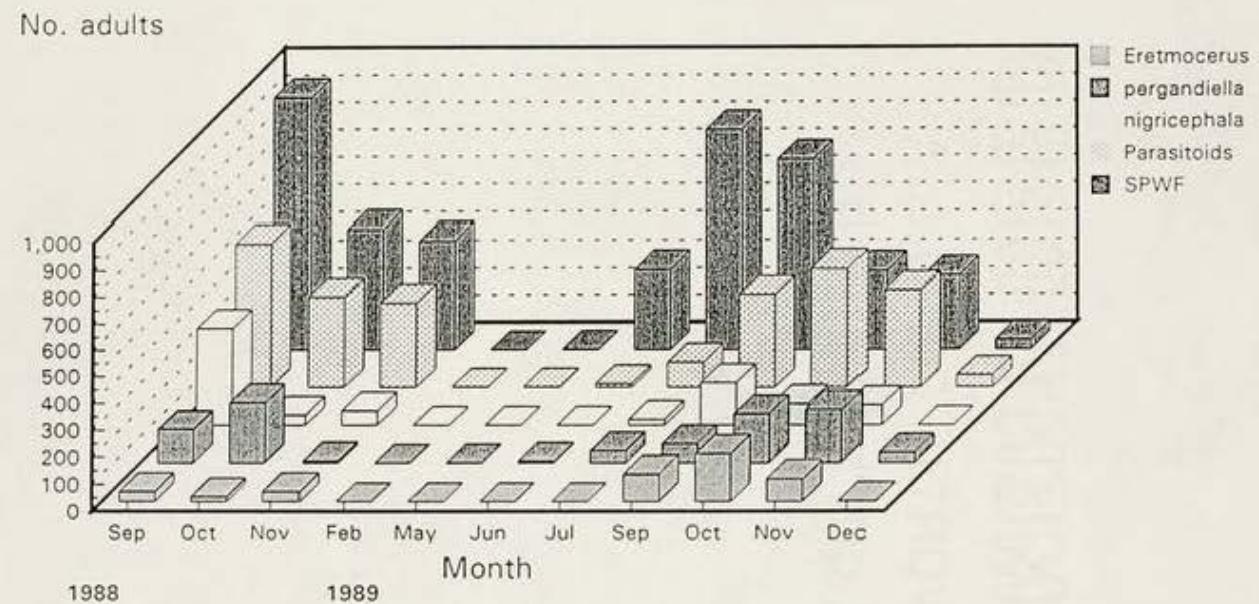


Figure 8.8. SPWF and parasitoids (total number) reared from wild and cultivated hosts, Gainesville: 1988-1989.

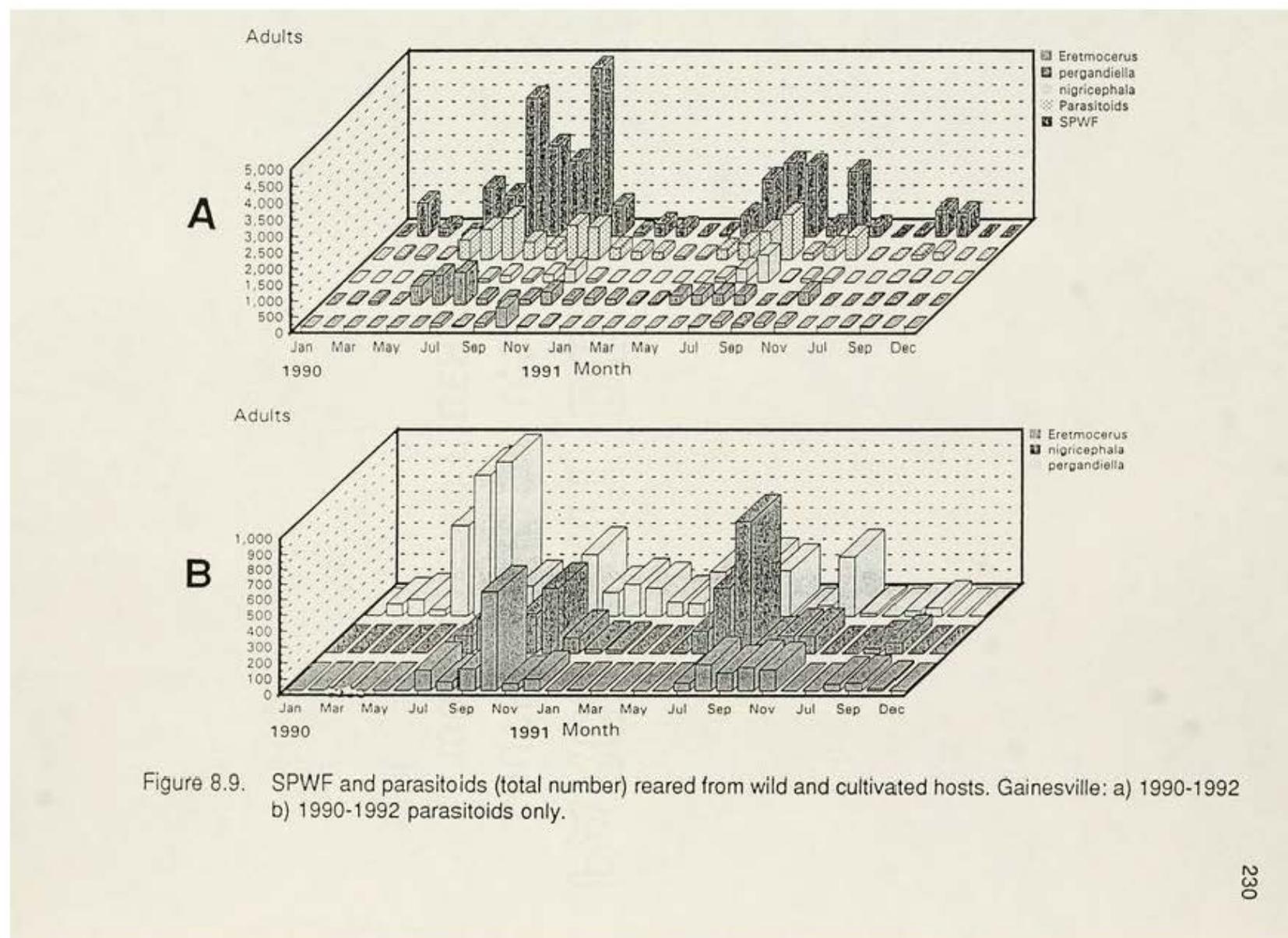


Figure 8.9. SPWF and parasitoids (total number) reared from wild and cultivated hosts. Gainesville: a) 1990-1992
 b) 1990-1992 parasitoids only.

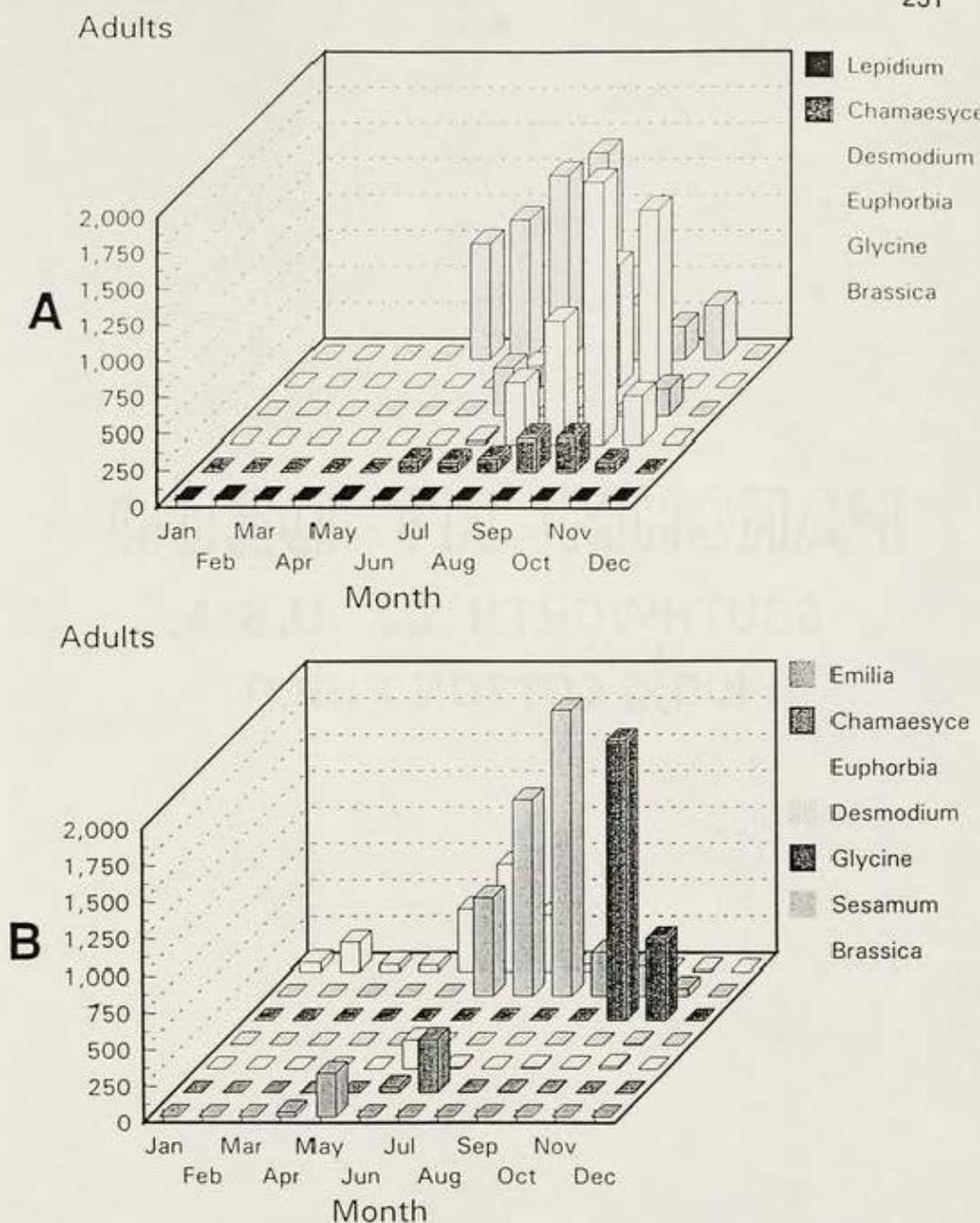


Figure 8.10. Seasonality of SPWF (total number) on different host plants. Gainesville. a) 1990 b) 1991.

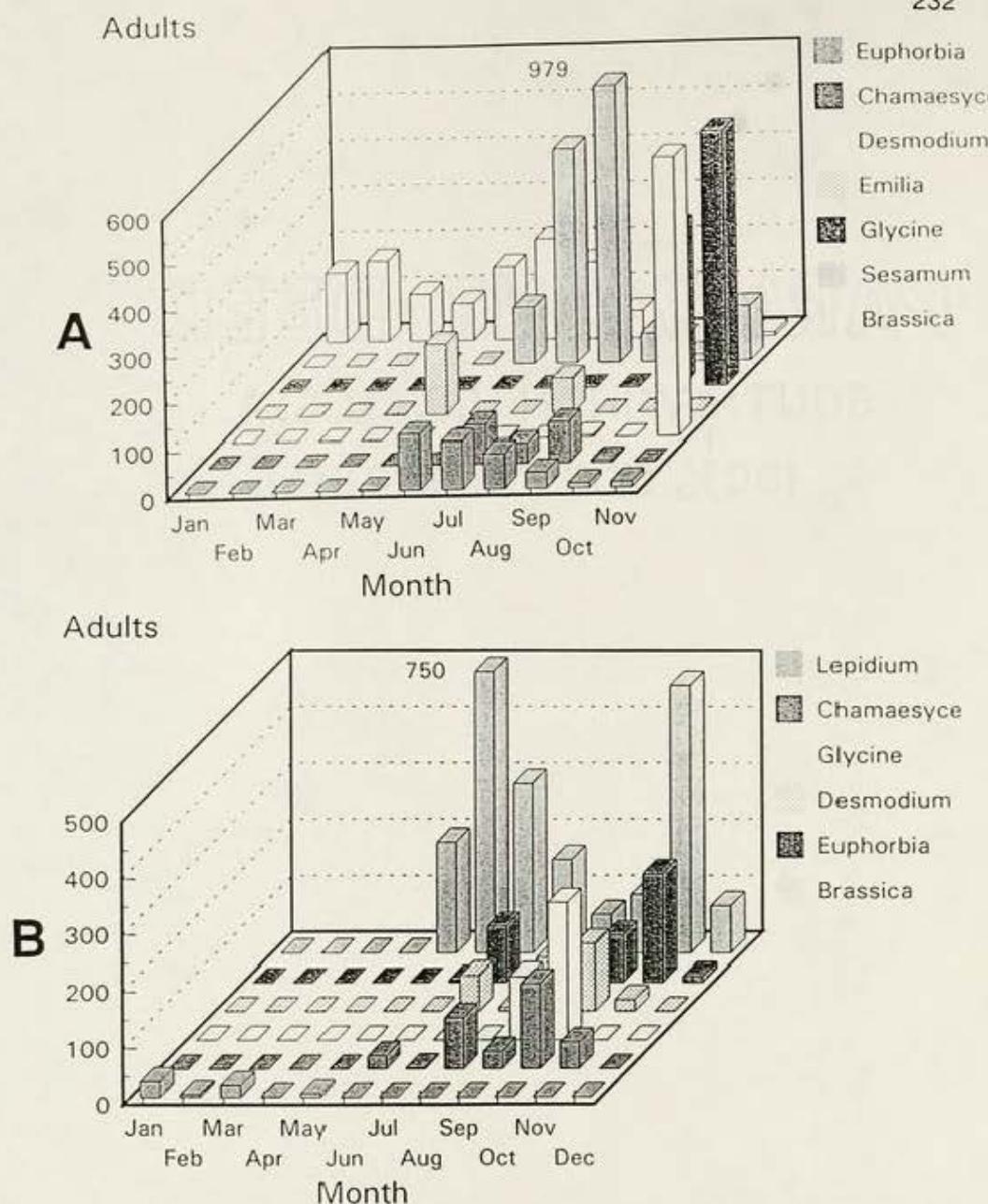


Figure 8.11. Seasonality of parasitoids (total number) reared from SPWF on different host plants. Gainesville. a) 1990 b) 1991.

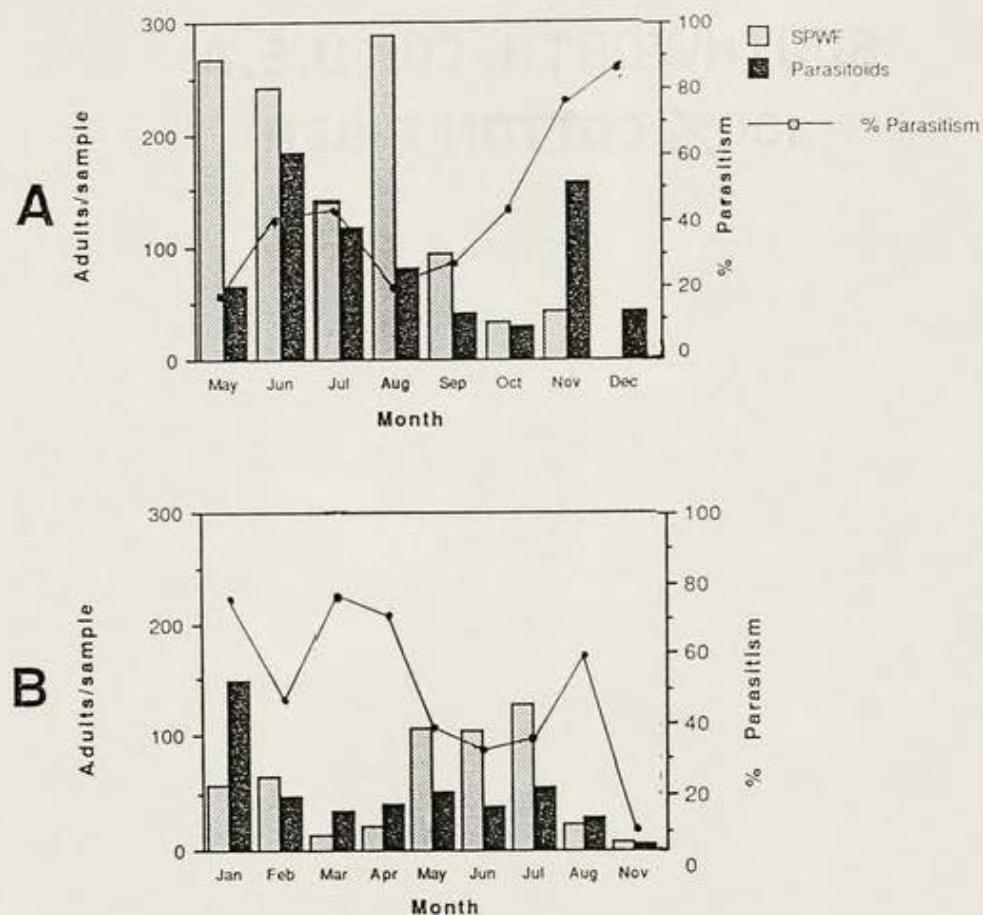


Figure 8.12. SPWF and parasitoids (mean/sample) reared from *Brassica oleracea acephala* and % parasitism. Gainesville a) 1990 b) 1991.

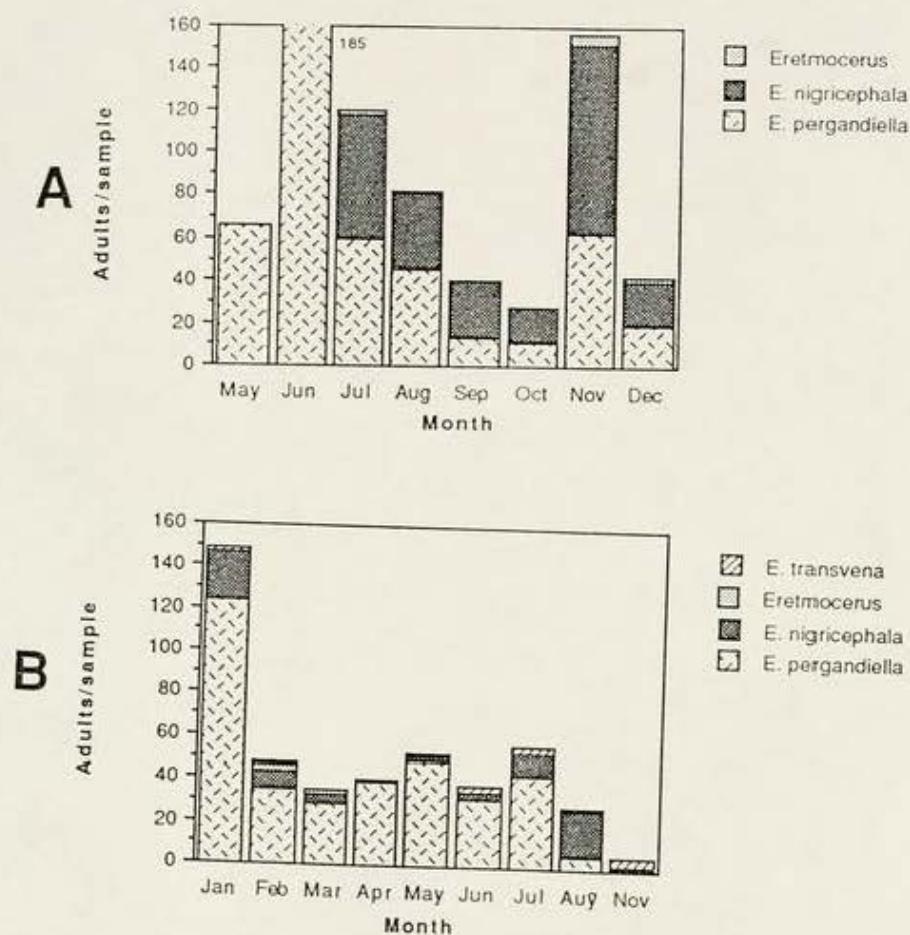


Figure 8.13. Parasitoids reared from SPWF on *Brassica oleracea acephala*. Gainesville. a) 1990 b) 1991.

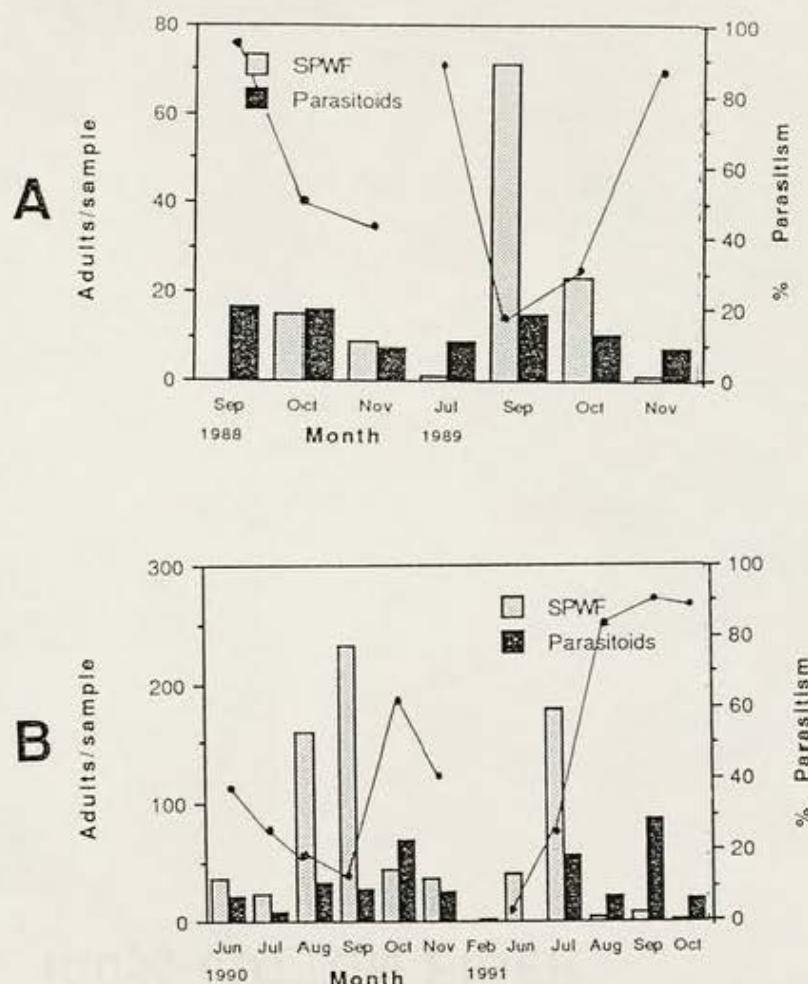


Figure 8.14. SPWF and parasitoid species (mean/sample) reared from *Chamaesyce hyssopifolia* and % parasitism. Gainesville a) 1988-1989 b) 1990-1991.

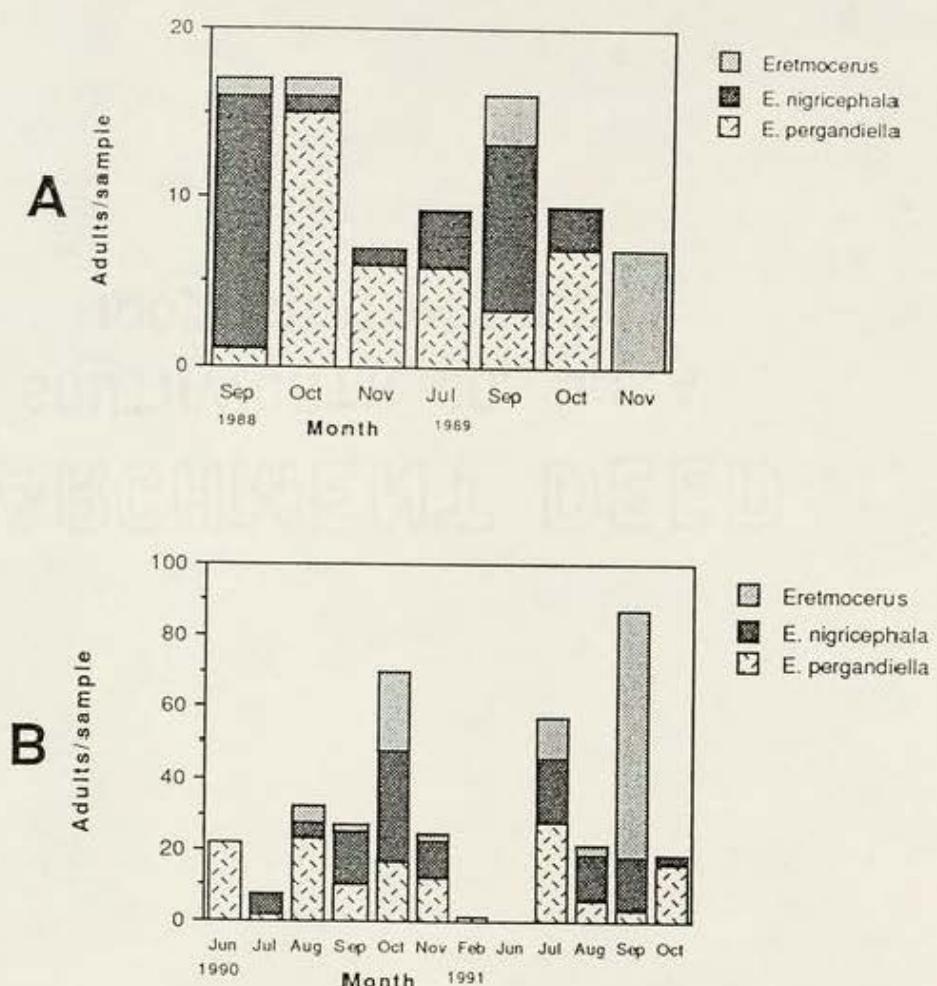


Figure 8.15. Parasitoid species (mean/sample) reared from SPWF on *Chamaesyce hyssopifolia*, Gainesville. a) 1988-1989 b) 1990-1991.

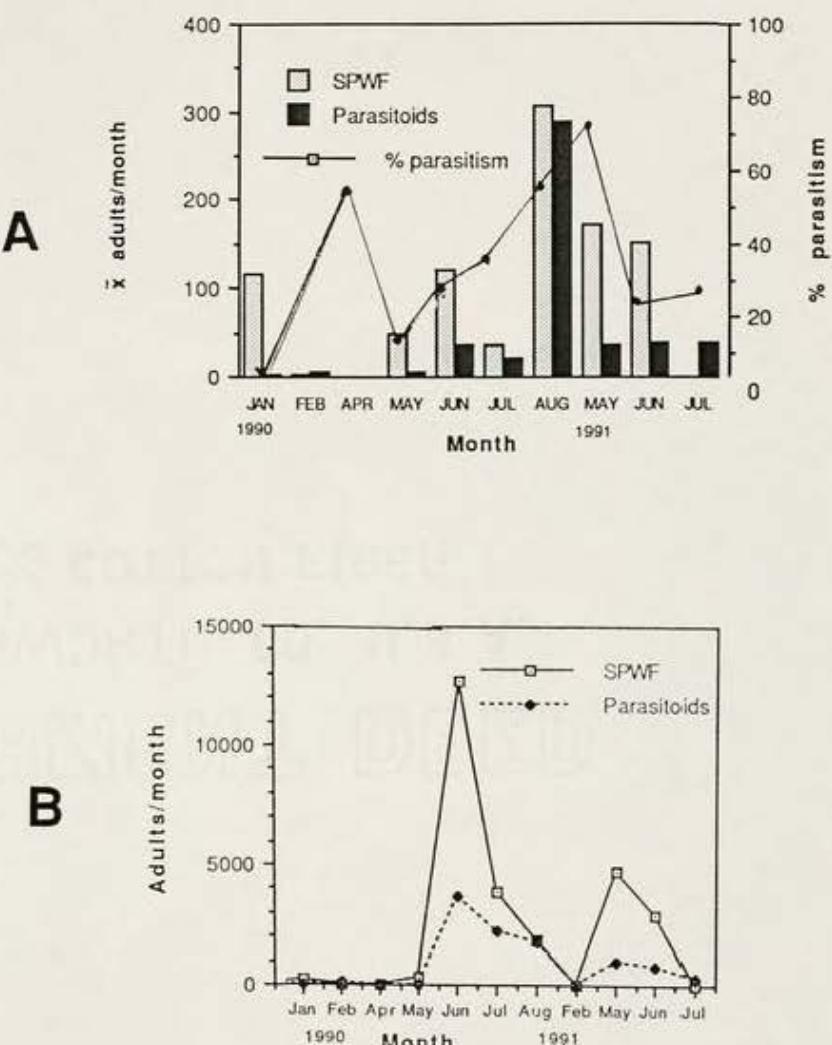


Figure 8.16. SPWF and parasitoids reared from wild and cultivated hosts and % parasitism: Bradenton 1990-1991. a) mean/sample b) total adults.

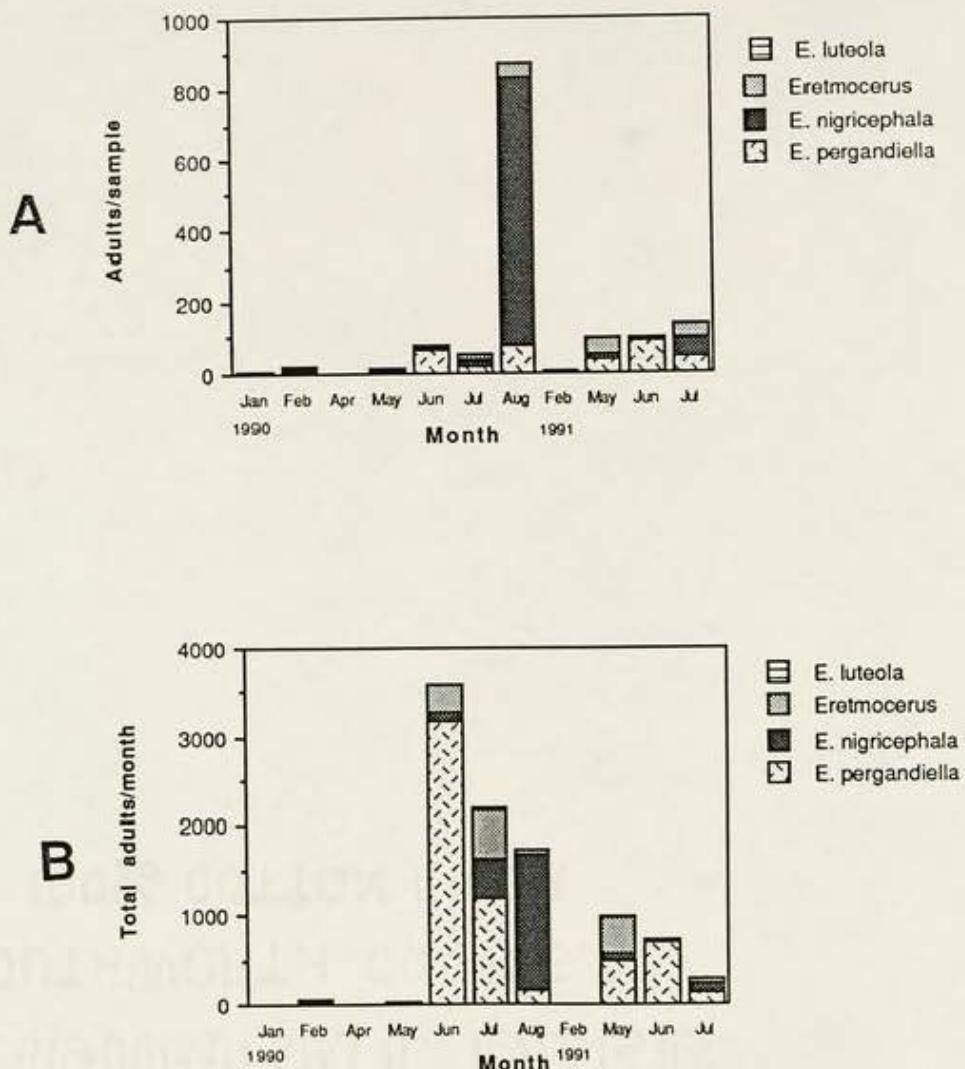


Figure 8.17. Parasitoid species reared from SPWF on wild and cultivated hosts. Bradenton: 1989-1991. a) mean/sample b) total

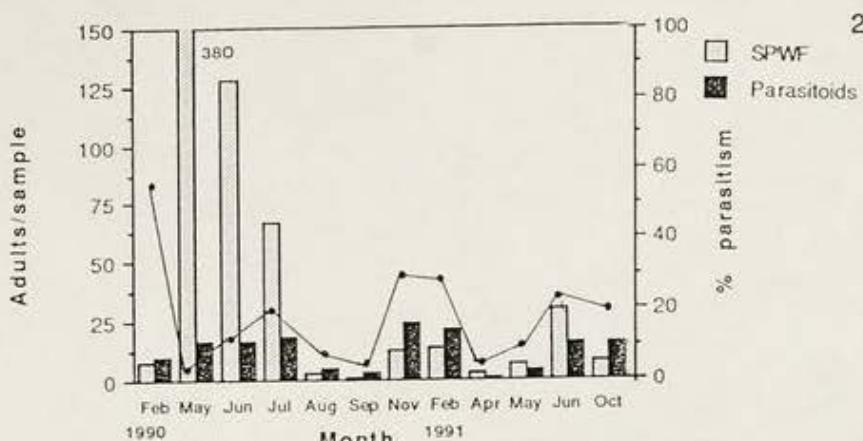


Figure 8.18. SPWF and parasitoids reared from wild and cultivated hosts and % parasitism. Homestead: 1990-1991.

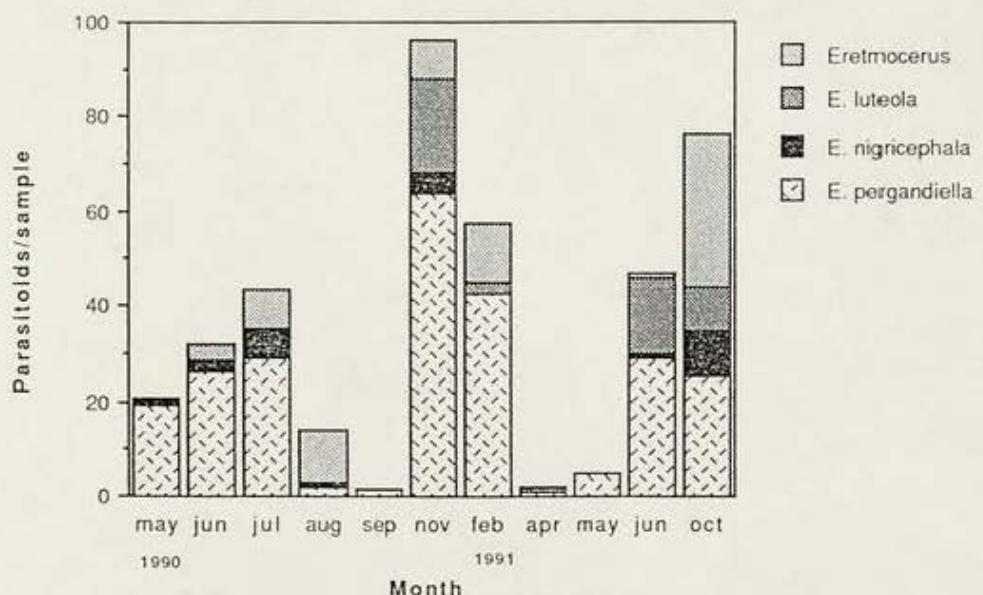


Figure 8.19. Parasitoid species reared from SPWF on wild and cultivated hosts. Homestead: 1990 to 1991.

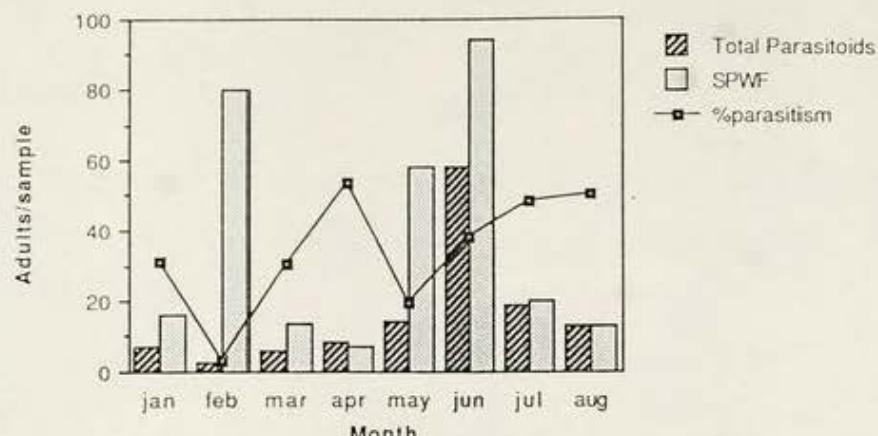


Figure 8.20. SPWF and parasitoids reared from wild and cultivated hosts and % parasitism. Immokalee: 1990-1991.

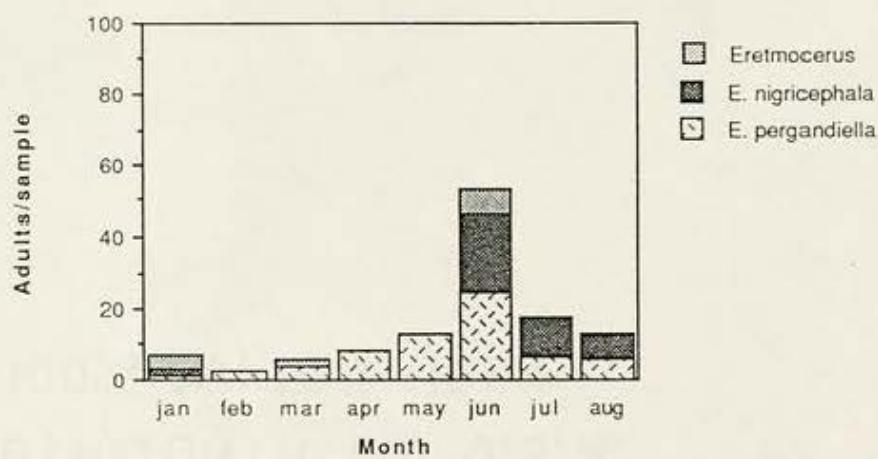


Figure 8.21. Parasitoid species (mean/sample) reared from SPWF on wild and cultivated hosts. Immokalee: 1990 to 1991.

CHAPTER 9

DISCUSSION

9.1. The Role of Systematics in Biological Control

Several authors (DeBach 1973; Clausen 1942; Sabrosky 1955) have commented on the importance of systematics to biological control. The most basic question to answer, and most important, is "what is it". The answer to the question may be the key that will unlock all the information that is currently known about the parasitoid, such as what are its hosts, where is its origin, etc. Very little was known about many of the parasitoid species in the survey; for many species, only the information associated with the holotype was known. Before describing new Encarsia species discovered in the survey, it was necessary to gather taxonomic information and examine all of the Encarsia species already described from the New World, and many of those described from outside the area. The gathering of the taxonomic knowledge often provided additional information on the host, geographic distribution and sometimes biology of the parasitoid species.

The identity of the parasitoid should be determined before initiating biological studies on the organism in order to avoid duplication of previous work performed on the same species and to be able to compare independent results on

the same species. Much of the time and effort spent on the introduction of exotic parasitoids may be avoided by determining the parasitoid species already present in the area. For example, E. pergandiella and E. transvena were sent from Guatemala and India, respectively, to the Gainesville quarantine facility for evaluation. Through the extensive survey that was carried out in Florida, we know that both of these parasitoids are already present in Florida, and therefore do not need to be cultured and tested for introduction. Determining the parasitoid species and their relative abundance in the area before exotic species are introduced, is important in order to document the possible displacement of the native species by the exotic species (Bennett, 1992).

Systematics is particularly important in the utilization of aphelinids in a biological control program. There are several examples of where a race or strain of a parasitoid species has played an important role in biological control (DeBach 1977). A given parasitoid species may have forms that are better adapted to certain areas and conditions or to different hosts; they may develop faster or produce more progeny on certain host insects and plants than on others. There may be forms that differ in their mode of reproduction, some may have both asexually and sexually reproducing forms (Stouthamer & Luck 1991). Their taxonomic status is often difficult to determine, but their identification and subsequent utilization may be very important to the biological control of the organism.

This study provides the basis of what is known of the New World Encarsia fauna that parasitize whiteflies. Several important taxonomic questions have been answered during its process. The synonymy of Encarsia tabacivora with E. pergandiella was determined by examination of hundreds of specimens from different hosts and from different geographic locations from New York to Argentina. We have been able to gain insight as to how the morphology of a parasitoid species may be affected when reared from different host species, as well as other intraspecific variations that occur. Several ancillary benefits that have been achieved through the study of the SPWF parasitoid fauna. This study provides the means for recognition of many Encarsia species that attack other whiteflies, a basis for placing them in species groups, and provides taxonomic references for more detailed study.

Several taxonomic problems remain unresolved. Most of these problems can be attributed to the dilemma of determining whether slight morphological differences in individuals represent distinct species or intraspecific variation of the same species. Also, determining separate taxonomic status of cryptic species, or species races or strains, is often difficult.

The identification of morphologically similar species or races may not be possible through conventional taxonomic techniques. Current methods for separating closely related organisms include DNA analyses, morphometrics and biological reproductive crossing experiments.

9.2 Biological Control of the SPWF

The current prospects for biological control of the SPWF using parasitoids are still largely unexplored. Effective parasitoids are needed to control SPWF populations in both glasshouse and field settings. For field populations, biological control may not be the solution; Horowitz (1986) indicated that abiotic factors were the main governing factors regulating SPWF populations. The present study shows that Florida is one of the richest areas of diversity of *Encarsia* parasitoids. In California there is also a wide range of naturally occurring parasitoids of the SPWF present, but studies by Coudriet et al. (1986) showed that levels of parasitism never exceeded 40%.

Perhaps more importantly than the number of different parasitoid species in the area, is the composition of the parasitoid complex of the area. Although there are 13 parasitoid species that attack the SPWF in Florida, three species comprise 98.5% of the total parasitoids reared from SPWF, and one species is particularly dominant throughout most of the year.

Parasitoids have the potential to play a much larger role in the control of the SPWF. Foreign exploration may lead to the discovery of more effective parasitoid species and/or species strains or biotypes. Understanding the biology and relationships of the SPWF and its parasitoids may improve parasitoid efficiency through proper timing of parasitoid releases and managing each parasitoid species according to its needs and effectiveness. Augmentation and conservation of parasitoid species and their integration with other methods of control, will be important to the overall management of the SPWF.

9.2.1. Parasitoid Requirements

9.2.1.1. Affinity to parasitize the SPWF

Of the 56 New World Encarsia species, only 15 are known to parasitize the SPWF; of these 15 species, E. formosa, E. strenua and E. quaintancei, prefer to parasitize other species of whiteflies. Only 5 of the remaining 12 Encarsia species, are reared frequently and in large numbers from SPWF.

Only one species in the genus Amitus (a new species) is known to attack the SPWF. At least 3 species of the genus Eretmocerus parasitize the SPWF in Florida. Undoubtedly, other Eretmocerus species which attack the SPWF will be recognized once the systematics of the genus is better understood.

Seven Encarsia species have been recorded as parasitoids of the SPWF in other parts of the world that could be introduced for the control of SPWF (Polaszek et al. 1992). Foreign exploration is currently being carried out in Europe, Pakistan, India and other areas for natural enemies of the SPWF. The parasitoids of the SPWF are virtually unknown in most areas of the world. Strains or biotypes may exist, that could be useful in the biological control of the SPWF.

9.2.1.2. Synchronization of Life Cycles

The results of the population trends of the SPWF and its parasitoids indicate the importance of controlling the SPWF population during the early phases of its development. The reproductive capacity of the SPWF is much greater than that of the parasitoids. Parasitoids need to be present in large enough numbers to

overcome the large increase in the SPWF population; in Gainesville, this occurs in May. Increasing the number of parasitoids during the early part of the year, can be achieved by rearing and releasing large numbers of parasitoids, or by allowing the parasitoid population to build-up by inoculating the field with SPWF or with an alternate host whitefly species. Hoelmer and Osborne (1990) suggested that the host specific, papaya whitefly, *Trialeurodes variabilis*, could be used as a "banker" host for SPWF parasitoids. The parasitoid population builds-up in adequate numbers on the non-noxious host, and shifts to the SPWF to counteract large increases in the SPWF population.

Osborne (1981) commented on the importance of using physiological time of the parasitoid to predict when parasitoids should be released. Releases of *E. formosa* adults were made to coincide with the presence of the preferred stage of the host and pesticides were applied to minimize their effect on parasitoid emergence.

Foster and Kelly (1978) discussed the importance of whitefly density to the successful introduction of *E. formosa* to control *T. vaporariorum* on tomato. They concluded that an initial density of one adult whitefly per 10 tomato leaves would be the "ceiling" for the successful introduction of *E. formosa*; greater densities would result in failure of the parasitoid to control its host.

9.2.1.3. Asexual versus Sexual Parasitoid Species.

Controversy has arisen over the introduction of parasitoid species which

have hyperparasitic males for the biological control of the SPWF (Faust, 1991). Stouthamer (1993) reviewed the advantages and disadvantages of parasitoids having asexual and sexual modes of reproduction. Both sexual and asexual forms are known of many hymenopteran species. Such conspecifics forms either occur sympatrically or are found in different geographic areas. Also, asexual individuals can be found in many predominantly sexual populations (Aeschlimann, 1990).

Sexual forms will likely be able to adapt faster to changed circumstances. Therefore, if the area in which the wasps are released differs in many ways from that in which the wasps were collected, sexual forms may have an advantage. Assuming the asexual and the sexual form produce the same number of progeny, the asexual one will have a higher rate of population increase because it does not "waste" eggs for producing males, or "waste" hosts for the production of males when the host population is low. Thus the cost per asexual female should be less than per sexual female. For parasitoids used in inundative releases, this is a big advantage. Sexual forms must mate to produce female offspring, therefore in situations where the wasp population density is very low, male and females may have problems encountering each other. Asexual forms do not suffer from this Allee effect (Allee, 1931); therefore, they are better colonizers. Asexual forms should be able to suppress host populations to lower levels than a comparable sexual form, since they are not limited by the scarcity of males when the host population is low.

In some cases, offspring production of asexual forms is much lower

(sometimes 50% lower) than that of sexual forms. This occurs more frequently when more hosts are present than can be parasitized; however, when fewer hosts are available, asexual forms may produce higher numbers of offspring than sexual forms. When given a choice, sexual forms are recommended to be used where large numbers of hosts occur, and asexual forms are to be used when the host density is lower and for inundative releases (Stouthamer, 1993).

Adelphoparasitism occurring in several Encarsia species is an additional factor to consider. Males in these species may destroy conspecific females, but many are known to preferentially destroy other parasitoid species (Sailer and Nguyen, 198 ; Williams 1990). Stouthamer's arguments for the advantages and disadvantages of sexually versus asexually reproducing species, plus the effects of adelphoparasitism, may explain the predominance of E. pergandiella during the summer months in Gainesville.

E. pergandiella is a sexually reproducing parasitoid species with a relatively short developmental rate and hyperparasitic males. During the early part of the year, when SPWF hosts and males of E. pergandiella are less abundant, females tend to lay a higher proportion of male eggs (some multiparasitism occurs), that may be preferentially laid in other parasitoid species. The population of Eretmocerus, E. nigricephalus and other parasitoids, decreases and remains very low until late July. With the large increase in the SPWF population in late May and early June, there are abundant host available, and E. pergandiella lays a higher proportion of female eggs. Following Stouthamer's argument, that sexual forms

produce more eggs than asexual forms, *E. pergandiella* out-competes the other parasitoid species; its dominance over *Eretmocerus* may be due to its shorter life cycle and hyperparasitic males. The population of *Eretmocerus* and *E. nigriccephala* increases in late summer, possibly due to the large number SPWF hosts available and a decrease in hyperparasitism by *E. pergandiella* males.

Parasitoid species whose males are very rare or unknown, *Amitus* sp., *E. formosa*, *E. strenua* and *E. citrella*, were infrequently reared from SPWF collections. *Amitus* has a very long developmental rate (27 days at 25 C) and has rarely been recovered in areas where it had been previously released (R. Nguyen, personal communication). The latter three species are primarily parasitoids of other species of whiteflies, and are not often reared from the SPWF. A "strain" of *E. formosa* has been discovered that supposedly is more aggressive on the SPWF and has been given the name the "Beltsville strain" (J. Bentz, personal communication). The parasitoid has been reared under glasshouse conditions, but has not yet been tested under field conditions.

The sex ratio varies considerably among biparental *Encarsia* species; *E. pergandiella*, *E. luteola*, and *E. nigriccephala* average about 60, 70 and 85% female, respectively. Several collections containing large numbers *E. pergandiella* females (no males) were reared from SPWF in certain areas, indicating the possible existence of asexual populations of this species.

9.2.1.4. Parasitoid Fecundity and Developmental Rate

Fecundity and developmental rate may vary between species and are greatly influenced by environmental conditions, especially temperature and humidity. *E. transvena* has a very short life cycle (about 15 days), and produces adelphoparasitic males that have been observed parasitizing *Eretmocerus* species in SPWF (K. Hoelmer, personal communication). *E. transvena* is a more prominent parasitoid of SPWF in southern Florida and has displaced *E. pergandiella* in glasshouse colonies (Schuster, personal communication). It occurs in the Gainesville area, but is rarely collected. Apparently, it is not well adapted to more northern climate or is dominated by *E. pergandiella*.

9.2.2. Parasitoid Utilization

9.2.2.1. Current Status

The parasitoid species that are already present in Florida, as they are used now, have been unable to maintain the SPWF population below economic levels. Several exotic parasitoid species that attack the SPWF are currently being reviewed for introduction. It is unlikely that a single parasitoid species will provide the level of control required to maintain the SPWF population below economic levels under all of the conditions on which it must perform.

There are often several factors to consider in order to use each parasitoid species effectively. For example, *Eretmocerus* may be useful under glasshouse conditions, where the researcher or grower has the ability to exclude hyperparasites from the environment. *Eretmocerus* species have a slightly longer

life-cycle than Encarsia species, but population tend to build-up quickly. However, Eretmocerus may not be useful to control SPWF on host plants with very hairy leaves. Amitus is more effective in controlling high populations of SPWF, than when the SPWF population is low.

Encarsia transvena has a very short lifecycle and may be effective in controlling SPWF in glasshouses and under field conditions in warmer climates, but may not be effective under cooler conditions in the more northern areas. It is possible that the effectiveness of parasitoids already present, such as E. pergandiella and E. nigriceps, may be enhanced through conservation, augmentation and manipulation.

9.2.2.2. Parasitoid Conservation

Conservation practices can be used separately or in conjunction with parasitoid augmentation programs to increase the number of parasitoids in an area. Weeds that harbor a disproportionately higher percentage of SPWF than parasitoids, may be eliminated in order to decrease the number of SPWF in the area. Weed species that harbor higher numbers of parasitoids, or those that harbors higher percentages of a given parasitoid species, may be conserved. Maintaining these plants in the field during the winter months may be beneficial as they provide a refuge for the parasitoids. Emilia may be a useful weed for its relatively low SPWF:Parasitoid ratio, and high mean number of parasitoids. Desmodium, on the other hand, may be a less desirable weed for its very high

SPWF:Parasitoid ratio and a relatively low number of parasitoids. A higher proportion of Eretmocerus were reared from Cassia than most other host plants. Preferentially conserving host plants with higher Eretmocerus population may be useful since both males and females of this genus are primary parasitoids.

9.2.2.3. Augmentation and Manipulation

Limiting the occurrence of hyperparasitism by Encarsia pergandiella males may allow other parasitoid species to develop; this increased diversity of parasitoid species may lead to better control of the SPWF. Ways of limiting hyperparasitism include killing-off E. pergandiella early in the season, then releasing large numbers of Eretmocerus or a non-hyperparasitic species in the area; releasing large numbers E. pergandiella males in the area that would fertilize a larger proportion of females than otherwise would occur, and thus, lay a higher proportion of female eggs; release a species that develops during the early spring on which male E. pergandiella and other heteronomous parasitoid species can develop; search for and introduce parasitoid species that have attributes that can counteract the hyperparasitic males; select females of the heteronomous parasitoid that lay a disproportionate number of female eggs; and provide E. pergandiella and other parasitoid species with an adequate supply of alternate host individuals, so that they will lay a greater number of female eggs than would normally occur. The latter method is most preferred, provided that the parasitoids move freely onto the SPWF from their alternate host species.

The use of parasitoids to manage SPWF populations may be more feasible in glasshouses than under field conditions, because of the ability to control the environment. SPWF populations can be carefully monitored and parasitoids reared and released in large numbers at precise times and under favorable conditions in the glasshouse. Also, hyperparasitoids and natural enemies of the parasitoids can be excluded. For example, Eretmocerus may be very effective in glasshouse conditions, whereas in the field, it may be attacked by hyperparasitic Encarsia males. Monitoring SPWF populations in the field is more difficult and the parasitoids may be exposed to unfavorable conditions and natural enemies. Unexpected fluctuations in the SPWF population may occur when large numbers migrate into the area.

9.2.2.4. Integrated Pest Management

The use of parasitoids is only one of several control measures that need to be employed in order to achieve the successful control of the SPWF. Knowledge of the systematics and biology of each parasitoid species and how they can be integrated with other control measures and farming practices are key elements in the overall development of management strategy for the SPWF.

Quezada and Saunders (1989) suggested an IPM program for SPWF on food crops that included cultural practices, weed management, insecticide resistance management, rational use of pesticides, resistant cultivars and training of farm workers. Parrella (1991) was able to decrease the SPWF population on

greenhouse poinsettia plants 10 to 100 times less than those in control plots by using the combination of insecticidal soap, roguing of obviously infested cuttings and weekly releases of 3 to 5 E. formosa parasitoids/plant.

Cultural practices, such as maintaining tomato seedlings under polyester covers, may help reduce SPWF, by reducing the initial inoculum in the field (Nawick et al. 1985). Host plant resistance in cotton, tomatoes and other crops is currently being explored (Ahmed et al. 1987; Berlinger, 1986; Prabhaker, Coudriet & Meyerdirk, 1985; O.M. B. de Ponti et al. 1990).

Rational use of pesticides is necessary to decrease pesticide resistance of the SPWF and conserve its natural enemy fauna. Several biorational insecticides are currently being reviewed. Neem was found to suppress SPWF nymphal development; only 14.3 and 13.0% of the SPWF nymphs reached the adult stage when 0.5 and 1.0% neem oil were applied (Natarajan, 1990). Osborne (1981) found that there was no significant reduction in parasitoid (Encarsia formosa) emergence when black-parasitized pupae of Trialeurodes vaporariorum were treated with resmethrin.

Butler et al. (1989) found that cotton seed oil applied to cotton, repelled SPWF adults for 9 days. Applications of liquid detergents decreases SPWF populations on cotton and watermelon (Butler, 1990). Synergists have been used in conjunction with pesticide sprays to counteract the development of physiological resistance by the SPWF (Prabhaker et al. 1988).

The concerted use of pathogens, predators and parasitoids, shows promise

in controlling the SPWF, especially in the glasshouse environment. The fungus, Paecilomyces fumosaroseus may cause high SPWF mortality, but is limited by low relative humidity. In the glasshouse, the environment can be controlled, to provide the conditions necessary for the development of the fungus. Osborne and Landa (1992) and Fransen (1990) discuss the use of pathogens for the biological control of the SPWF. Hoelmer (1990) and Gerling (1990) examined the use of predators as biological control agents of the SPWF. Delphastus pusillus (Coccinellidae) and phytoseiid mites were among the most important predators of the SPWF.

The magnitude of the role parasitoids will play in the control of the SPWF will be greatly influenced by our ability to recognize and utilize parasitoid species and biotypes. Knowledge of the systematics and biology of each parasitoid species and how they can be integrated with other control measures and farming practices will be key elements in the overall development of management strategy for the SPWF.

APPENDIX A
Whitefly Host-Parasitoid List

Aleyrodidae

1. *Aleurocanthus citriperdus* Quaintance & Baker
 Encarsia sp.
 +*Encarsia divergens* Silvestri:(Fulmek 1943)
 +*Encarsia merceti* Silvestri:(Fulmek 1943)
 +*Encarsia smithi* Silvestri:(Fulmek 1943)

2. *Aleurocanthus spiniferus* (Kuwana)
 +*Encarsia clypealis* (Silvestri):(Fulmek 1943)
 +*Encarsia divergens* (Silvestri):(Gerling 1970)
 +*Encarsia ishii* (Silvestri):(Thompson 1950)
 +*Encarsia merceti* Silvestri:(Fulmek 1943)
 +*Encarsia merceti* var *modesta* Silvestri
 +*Encarsia nipponica* Silvestri:(Fulmek 1943)
 +*Encarsia smithi* (Silvestri):(Fulmek 1943)
 +*Encarsia* sp. (Fulmek 1943)

3. *Aleurocanthus woglumi* Ashby
 Host Plant: (36,38)
Amitus hesperidum Silvestri
Encarsia opulenta (Silvestri)
Encarsia elongata Dozier
Encarsia variegata Howard
Amitus hesperidum Silvestri
 +*Encarsia merceti* Silvestri:(Thompson 1950)
 +*Encarsia divergens* Silvestri:(Thompson 1950)

4. *Aleurocanthus* sp.
Encarsia opulenta (Silvestri)
Encarsia sp.

5. *Aleurodicinae*
 Host Plant: (40)
Encarsia basicincta Gahan
Eretmocerus portoricensis Dozier

6. *Aleurodinus nr. cocois* (Curtis)
 Host Plants: (27, 40)
Encarsia luteola Howard
Encarsia strenua (Silvestri)
Encarsia variegata Howard
Encarsia sp.
Euderomphale sp.

6. *Aleurodinus nr. cocois* (Curtis) cont.
Amitus sp.
Encarsia formosa Gahan
Encarsia strenua (Silvestri)
Encarsia sp.

7. *Aleurodinus dispersus* Russell
 Host Plants :
 (11,19,22,42,109,110,129,153,168)
Encarsia haitiensis Dozier
Encarsia lahorensis (Howard)
Encarsia pergandiella Howard
Encarsia sp.
Euderomphale subvittata
Euderomphale vittata
Euderomphale sp.
Signiphora sp.

8. *Aleurodinus fluminensis*
 Host Plant: (26)

9. *Aleurodinus iridescentis* Cockerell
 (=*A. cocois* (Curtis) in Mound 1987.
Encarsia sp.
Euderomphale sp.

10. *Aleurodinus juleikae* Bondar
 Host Plants: (26,168)

11. *Aleurodinus* sp.
 Host Plants: (26,36,168)
ciliata (Gahan)

12. *Aleuroglandulus malangae* Russell
 Host Plants: (44,66,164)
Amitus sp. B
Encarsia formosa Gahan
Encarsia meritoria Gahan
Encarsia strenua group
Eretmocerus sp.

+ indicates literature record

13. *Aleuroplatus coronata* (Quaintance)
E. citrella (Gahan)
+*Encarsia auranti* (Howard) [?]: (Fulmek 1943)
+*Encarsia pergandiella* Howard: (Dysart 1966)
+*Encarsia citrella* Howard: (Fulmek 1943)
14. *Aleuroplatus elemerae* Mound
Host Plant: (102)
Encarsia strenua (Silvestri)
15. *Aleuroplatus ilicis* Russell
Host Plant: (84)
16. *Aleuroplatus plumosus*
Host Plant: (128)
17. *Aleuroplatus* sp.
Host plant: (137)
18. *Aleuroplatus vaccinum*
Host plant: (159)
19. *Aleuropleurocelus (=Tetralecia) granulata*
(Sampson & Drews)
Host Plants: (29,35)
20. *Aleurothrixus aepim* (Goldi)
Host Plants: (108, 129)
Encarsia cubensis Gahan or near
Encarsia opulenta (Silvestri)
Signiphora xanthographa Blanchard
21. *Aleurothrixus floccosus* (Maskell)
Host Plants: (34,36,38,39,40,61
104,129,138,168)
Amitus sp.
Cales noacki Howard
Encarsia americana DeBach & Rose
Encarsia basicincta Gahan
+*Encarsia bella* Gahan: (Fulmek 1943)
[prob. misidentification]
Encarsia brasiliensis (Hempel)
Encarsia cubensis Gahan
Encarsia elongata
+ *Encarsia haitiensis* Dozier: (Fulmek 1943)
Encarsia luteola Howard
Encarsia nigricephala Dozier
Encarsia pergandiella Howard
Encarsia variegata Howard
Encarsia sp.
Encarsiella nr. noyesi
Eretmocerus portoricensis Dozier
Eretmocerus sp.
Signiphora xanthographa Blanchard
22. *Aleurothrixus* sp.
Host Plants: (40,42,72)
23. *Aleurotrachelus atratus* Hempel
Host Plant: (42)
Encarsia nigricephala Dozier
Encarsia variegata Howard
24. *Aleurotrachelus trachoides* (Back)
Host Plants: (43,152,168)
Encarsia cubensis Gahan
Encarsia formosa Gahan
Encarsia pergandiella
Encarsia sp.
Eretmocerus sp.
25. *Aleurotrachelus* sp.
Host Plants: (41,114,160)
Encarsia sp.
Euderomphale sp.
26. *Aleyrodes* sp. on climbing vine
+*brunnea* (Howard)
27. *Aleyrodes* sp. on *Sonchus* sp.
+*coquillettii* Howard
28. *Bemisia tabaci* (Gennadius)
Host Plants: (1,2,4,5,6,7,8,9,10,11,13,14,15,
16,117,18,20,23,24,25,28,29,30,31,32,33,34,
37,41,44,45,47,48,49,50,51,52,53,54,55,58,59,
60,61,63,64,65,66,67,68,69,70,71,75,77,78,
79,81,82,83,86,87,88,89,92,93,94,95,96,97,
98,99,105,106,107,108,113,114,115,116,117,
118,119,120,123,124,125,127,129,132,134,
135,140,141,142,144,145,146,147,148,150,
151,154,155,156,157,163,167,168,169,170).
Amitus sp.
Encarsia desantisi Viggiani
Encarsia lutea Masi
Encarsia meritoria Gahan
Encarsia nigricephala Dozier
+*Encarsia partenopea* Masi (-inaron)
Encarsia pergandiella Howard
Encarsia porteri Mercet
Encarsia strenua (Silvestri)
Encarsia quaintancei Howard
Encarsia transvena (Timberlake)
Eretmocerus mundus Mercet
Eretmocerus sp.
Metaphycus sp.
Signiphora aleurodis Ashmead

29. *Crenidorsum* sp.*
 Host Plants: (43)
Encarsia citrella Howard
Encarsia formosa Gahan
Encarsia luteola Howard
Encarsia nigricephala Dozier
Encarsia strenua group
Eretmocerus sp.
Signiphora aleurodis Ashmead
30. *Dialeurodes citri* (Ashmead)
 Host Plants: (76,91,100,101,110,133,161)
Encarsia armata (Silvestri)
 +*Encarsia citrofila* (Silvestri):(Fulmek 1943)
Encarsia formosa Gahan
Encarsia lahorensis (Howard)
Encarsia pergandiella Howard
Encarsia strenua (Silvestri)
Encarsia transvena (Timberlake)
 +*Encarsia tricolor* Forster:(Ferriere 1965)
Encarsia variegata Howard
Eretmocerus sp.
31. *Dialeurodes citrifolii* (Morgan)
 Host Plant: (43)
Encarsia armata (Silvestri)
Encarsia lahorensis (Howard)
 +*Encarsia perstrenua* (Silvestri):(Fulmek 1943)
Encarsia strenua (Silvestri)
Encarsia transvena (Timberlake)
32. *Dialeurodes kirkaldyi* (Kotinsky)
 Host Plants: (91,168)
Encarsia lahorensis (Howard)
Encarsia strenua (Silvestri)
Eretmocerus sp.
33. *Dialeurodes* sp.
 Host Plant: (40)
Encarsia sp.
34. *Dialeurodicus* sp.(Aleurodicinae)
 Host Plant: (29)
Encarsia luteola Howard
Encarsia opulenta (Silvestri)
Encarsia strenua (Silvestri)
Eretmocerus sp.
Signiphora aleurodis Ashmead
35. *Lecanoideus giganteus* (Quaintance & Baker)
 Host Plant: (168)
Encarsia sp.
36. *Paraleyrodes minei laccarino* (Aleurodicinae)
 Host Plants: (36,38,40)
Encarsia brasiliensis or near
Encarsia herdoni (=elongata)
Encarsia parvella group
Encarsia variegata Howard
Encarsia sp.
37. *Parabemisia myricae* (Kuwana)
 Host Plants: (38,40)
 +*Encarsia bermiae* Ishii (=transvena):
 (Ishii 1938)
Eretmocerus sp.
38. *Tetraleurodes acaciae* (Quaintance)
 Host Plants: (13,33,56,62,77,93,126,168)
Amitus sp.
Encarsia meritaria Gahan
Encarsia nigricephala Dozier
Encarsia parvella group
Encarsia pergandiella Howard
Encarsia strenua group
Encarsia transvena (Timberlake)
Encarsia sp.
Signiphora aleurodis Ashmead
39. *Tetraleurodes fici* Quaintance & Baker
 Host Plant: (72)
 no parasitoids reared
40. *Tetraleurodes mori* (Quaintance)
 Host Plants: (73,84)
Amitus sp.
Encarsia formosa group
Encarsia parvella group
Eretmocerus sp.
41. *Tetraleurodes perileuca* (Cockerell)
 Host Plant: (130)
Amitus sp.
Encarsia sp.
42. *Trialeurodes abutiloneus* (Haldeman)
 Host Plants: (5,11,14,27,28,29,50,54,
 60,61,66,74,78,80,81,82,85,86,89,92,
 94,96,98,103,106,131,136,139,141,143,
 144,145,148,149,150,154,157,167,168)
Amitus sp.
Encarsia formosa Gahan
Encarsia hayati n. sp.
Encarsia luteola Howard
Encarsia nigricephala Dozier
Encarsia pergandiella Howard
Encarsia parvella group
Encarsia strenua group
Encarsia transvena (Timberlake)

42. *Trialeurodes abutiloneus* (Haldeman) cont.
Encarsia sp.
+*Eretmocerus haldemani* Howard:(Burk 1979)
Eretmocerus sp.
Signiphora aleurodis Ashmead
43. *Trialeurodes floridensis* (Quaintance)
Host Plants: (29,122)
Encarsia meritoria Gahan
Encarsia nigricephala Dozier
Encarsia pergandiella Howard
44. *Trialeurodes packardi* (Morrill)
Host Plants: (21,27)
+*Encarsia luteola* Howard:(Britton 1907)
Encarsia strenua (Silvestri)
Encarsia quaintancei Howard
Eretmocerus sp.
45. *Trialeurodes vaporiorarum* (Westwood)
Host Plants: 23,78,96,123,133,150,168)
Amitus fuscipennis
Encarsia desantisi Viggiani
Encarsia formosa Gahan
Encarsia luteola Howard
Encarsia meritoria Gahan
Encarsia parvella group
+ *Encarsia partenopea* Masi:(Fulmek 1943)
Encarsia pergandiella Howard
+*Encarsia porteri* Mercet:(Fulmek 1943)
Encarsia transvena(Timberlake):(Fulmek 1943)
Encarsia quaintancei Howard
Eretmocerus sp.
Signiphora aleurodis Ashmead
46. *Trialeurodes variabilis* (Quaintance)
Host Plant: (24)
Amitus sp.
Encarsia formosa group
Encarsia luteola Howard
Encarsia meritoria Gahan
Encarsia nigricephala Dozier
Encarsia pergandiella Howard
Encarsia strenua group
Encarsia transvena (Timberlake)
Eretmocerus sp.
47. *Trialeurodes* sp.
Host Plants: (11,12,14,35,46,50,53,
70,86,108,111,165,168)
Encarsia formosa Gahan
Encarsia lutea (Masi)
Encarsia nigricephala Dozier
Encarsia parvella group
Encarsia pergandiella Howard
Encarsia porteri Mercet
Encarsia strenua (Silvestri)
Encarsia transvena (Timberlake)
Signiphora aleurodis Ashmead
48. Unidentified whitefly
Host Plants: (90, 112,122,166)

APPENDIX B
Host Plant-Whitefly List

1.	<i>Abelmoschus esculentus</i> Bemisia tabaci	22.	<i>Canarium pimela</i> Aleurodicus dispersus
2.	<i>Acalypha gracilensis</i> Bemisia tabaci	23.	<i>Capsicum annuum</i> Bemisia tabaci, <i>Trialeurodes vaporiorum</i>
3.	<i>Acalypha</i> sp. Aleurodicus dispersus	24.	<i>Carica papaya</i> Bemisia tabaci, <i>Trialeurodes variabilis</i>
4.	<i>Acanthospermum hispidum</i> Bemisia tabaci	25.	<i>Cassia obtusifolia</i> Bemisia tabaci
5.	<i>Aeschynomene</i> sp. Bemisia tabaci	26.	<i>Cercropia</i> sp. Aleurodicus flumineus, A. sp.
6.	<i>Alysicarpus sativa</i> Bemisia tabaci	27.	<i>Cercis canadensis</i> Aleurodicus nr. <i>cocois</i> , <i>Trialeurodes abutiloneus</i> , T. <i>packardi</i>
7.	<i>Alysicarpus vaginalis</i> Bemisia tabaci	28.	<i>Chamaesyce hirta</i> Bemisia tabaci, <i>Trialeurodes abutiloneus</i>
8.	<i>Amaranthus</i> sp. Bemisia tabaci	29.	<i>Chamaesyce hyssopifolia</i> [Euphorbiaceae] Aleuropleurocelus granulata, Bemisia tabaci, <i>Dialeurodicus</i> sp., <i>Trialeurodes abutiloneus</i> , T. nr. <i>floridensis</i> .
9.	<i>Ambrosia</i> sp. Bemisia tabaci	30.	<i>Chamaesyce ophthalmica</i> Bemisia tabaci
10.	<i>Arachis hypogaea</i> Bemisia tabaci	31.	<i>Chamaesyce sador</i> Bemisia tabaci
11.	<i>Asteraceae</i> Aleurodicus dispersus, <i>Trialeurodes abutiloneus</i> , Bemisia tabaci	32.	<i>Chamaesyce thymifolia</i> Bemisia tabaci
12.	<i>Baltimora recta</i> <i>Trialeurodes</i> sp.	33.	<i>Chamaesyce</i> sp. Bemisia tabaci, <i>Tetraleurodes acaciae</i>
13.	<i>Bauhinia variegata</i> Bemisia tabaci, <i>Trialeurodes acaciae</i>	34.	<i>Chromolaena odorata</i> Aleurothrixus floccosus, Bemisia tabaci
14.	<i>Bidens pilosa</i> Bemisia tabaci, <i>Trialeurodes</i> sp.	35.	<i>Chrysanthemum</i> sp. Aleuropleurocelus granulata, <i>Trialeurodes</i> sp.
15.	<i>Boerhavia erecta</i> L. Bemisia tabaci	36.	<i>Citrus aurantifolia</i> Aleurocanthus woglumi, Aleurodicus sp., Aleurothrixus floccosus, Aleurothrixus sp., Paraleyrodes minei.
16.	<i>Brassica napus</i> Bemisia tabaci	37.	<i>Citrus lanatus</i> Bemisia tabaci(?)
17.	<i>Brassica oleracea capitata</i> Bemisia tabaci	38.	<i>Citrus sinensis</i> Aleurocanthus woglumi, Paraleyrodes minei, Parabemisiae myricae.
18.	<i>Brassica oleracea acephala</i> Bemisia tabaci	39.	<i>Citrus x paradisi</i> Aleurothrixus floccosus
19.	<i>Bucida buceras</i> Aleurodicus dispersus		
20.	<i>Cajanus cajan</i> Bemisia tabaci		
21.	<i>Callicarpa</i> sp. <i>Trialeurodes packardi</i>		

40.	Citrus sp. Aleurocanthus woglumi, Aleurodicinae, Aleurothrixus floccosus, A. sp., Dialeurodes citri, D. citrifolii, Paraleyrodes minei.	65.	Euphorbia gramineae Bemisia tabaci
41.	Cleome sp. Aleurothrichelus trachoides, Bemisia tabaci	66.	Euphorbia heterophylla Aleuroglandulus malangae, Bemisia tabaci Trialeurodes abutiloneus
42.	Cocos nucifera Aleurodicus ?cocois, A. dispersus, Aleurothrixus sp. not floccosus	67.	Euphorbia lactosa Bemisia tabaci
43.	Coccoloba uvifera Aleurothrixus trachoides, Crenidorsum sp.	68.	Euphorbia maculata Bemisia tabaci
44.	Colocasia esculenta Aleuroglandulus malangae	69.	Euphorbia pulcherrima Bemisia tabaci
45.	Convolvulus sp. Bemisia tabaci	70.	Euphorbia sp. Bemisia tabaci, Trialeurodes abutiloneus
46.	Cordia dentata Trialeurodes sp.	71.	Fabaceae Bemisia tabaci, Dialeurodicus sp.
47.	Crotalaria mucronata Bemisia tabaci	72.	Ficus sp. Aleurothrixus sp., Tetraleurodes fici
48.	Crotalaria spectabilis Bemisia tabaci	73.	Forsythia sp. Tetraleurodes mori
49.	Crotalaria sp. Bemisia tabaci	74.	Galva sp. Trialeurodes abutiloneus?
50.	Cucumis melo Bemisia tabaci, Trialeurodes abutiloneus, Trialeurodes sp.	75.	Galinsoga sp. Bemisia tabaci
51.	Cucumis mixta [Cucurbitaceae] Bemisia tabaci	76.	Gardenia sp. Dialeurodes citri
52.	Cucumis pepo Bemisia tabaci	77.	Glycine maxima Bemisia tabaci, Tetraleurodes acaciae
53.	Cucurbita sp. Bemisia tabaci, Trialeurodes sp.	78.	Gossypium hirsutum Bemisia tabaci, Trialeurodes abutiloneus, T. vaporiorarum
54.	Desmodium geniculata Bemisia tabaci, Trialeurodes abutiloneus	79.	Helianthus sp. Bemisia tabaci
55.	Desmodium tortuosum Bemisia tabaci	80.	Heliantheae Trialeurodes abutiloneus
56.	Desmodium sp. Bemisia tabaci, Tetraleurodes acaciae	81.	Heterotheca subaxillaris Bemisia tabaci, Trialeurodes abutiloneus
57.	Dioscorea alata Dialeurodes citrifolii	82.	Hibiscus mutabilis Bemisia tabaci, Trialeurodes abutiloneus
58.	Dolichos lablab Bemisia tabaci	83.	Hibiscus rosasinensis Bemisia tabaci
59.	Eclipta alba Bemisia tabaci	84.	Ilex sp. Aleuroplatus ilicis, Tetraleurodes mori
60.	Emilia fosbergi Bemisia tabaci, Trialeurodes abutiloneus	85.	Impatiens balsamica Trialeurodes abutiloneus
61.	Emilia sonchifolia Aleurothrixus floccosus, Bemisia tabaci, Trialeurodes abutiloneus	86.	Indigofera hirsuta Bemisia tabaci, Trialeurodes abutiloneus T. sp.
62.	Erythrina sp. Tetraleurodes acaciae	87.	Indigofera spicata Bemisia tabaci
63.	Euphorbia cyathophora Bemisia tabaci	88.	Ipomoea batatas Bemisia tabaci
64.	Euphorbia glomerifera Bemisia tabaci	89.	Ipomoea sp. Bemisia tabaci, Trialeurodes abutiloneus
		90.	Ixora sp. aleurodidae

91.	Jasminum sp. Dialeurodes kirkaldyi	Bemisia tabaci Pachystachys sp.
92.	Jatropha gossypifolia Bemisia tabaci, Tetraleurodes acaciae, Trialeurodes abutiloneus	Bemisia tabaci Panicum adspersum Bemisia tabaci
93.	Jatropha sp. Bemisia tabaci	Parthenium sp. Bemisia tabaci
94.	Lactuca sp. Bemisia tabaci, Trialeurodes abutiloneus	Persea americana Trialeurodes floridensis
95.	Lagasca mollis Bemisia tabaci	Persea borbonia Trialeurodes floridensis
96.	Lantana camara Bemisia tabaci, Trialeurodes abutiloneus, T. vaporiorarum	Phaseolus vulgaris Bemisia tabaci, Trialeurodes vaporiorarum
97.	Lantana montevidensis Bemisia tabaci	Phyllanthus carolinensis Bemisia tabaci
98.	Lepidium virginicum Bemisia tabaci, Trialeurodes abutiloneus	Phyllanthus tenellus Bemisia tabaci
99.	Leucaena sp. Bemisia tabaci	Piscida piscipula Tetraleurodes acaciae
100.	Ligustrum sinense Dialeurodes citri	Polygonum sp. Bemisia tabaci
101.	Ligustrum sp. Dialeurodes citri	Prunus caroliniana Aleuroplatus plumosus
102.	Liquidamber styraciflua Aleuroplatus elemerae	Psidium guajava Aleurodicus dispersus, Aleurothrixus aepim, A. floccosus, Bemisia tabaci
103.	Lobelia cardinalis Trialeurodes abutiloneus	Quercus virginiana Tetraleurodes perileuca
104.	Loranthaleae Aleurothrixus floccosus	Quercus sp. Trialeurodes abutiloneus
105.	Ludwigia erecta Bemisia tabaci	Florida Red Vine Bemisia tabaci
106.	Lycopersicon lycopersicum Bemisia tabaci, Trialeurodes abutiloneus	Rhododendron sp. Dialeurodes citri, Trialeurodes vaporiorarum, Trialeurodes sp.
107.	Macroptilium lathyroides Bemisia tabaci	Ricinus communis Bemisia tabaci
108.	Manihot esculentum Aleurothrixus aepim, Bemisia tabaci, Trialeurodes sp.	Richardia scabra Bemisia tabaci
109.	Mangifera indica Aleurodicus dispersus	Ruta chapepeensis Trialeurodes abutiloneus
110.	Melia azedarach Aleurodicus dispersus, Dialeurodes citri	Saccharum officinarum Aleuroplatus sp.
111.	Melanthera nivea Trialeurodes sp.	Schinus terebinthifolius Aleurothrixus floccosus
112.	Melaleuca sp. aleyrodid	Senecio sp. Trialeurodes abutiloneus
113.	Morremia odorata Bemisia tabaci	Sesamum indicum Bemisia tabaci
114.	Nerium oleander Aleurotrachelus or n. gen.	Sesbania sp. Trialeurodes abutiloneus
115.	Nicandra physalodes Bemisia tabaci	Sida acuta Bemisia tabaci, Trialeurodes abutiloneus
116.	Nicotiana tabacum Bemisia tabaci	Sida sp. Bemisia tabaci, Trialeurodes abutiloneus
117.	Ocimum basilicum	

144.	<i>Solanum americanum</i>	
	<i>Bemisia tabaci</i> , <i>Trialeurodes abutiloneus</i>	Additions
145.	<i>Solanum melongena</i>	
	<i>Bemisia tabaci</i> , <i>Trialeurodes abutiloneus</i>	169. <i>Medicago sativa</i>
146.	<i>Solanum nigrum</i>	<i>Bemisia tabaci</i>
	<i>Bemisia tabaci</i>	170. <i>Physalis sp.</i>
147.	<i>Solanum nudum</i>	<i>Bemisia tabaci</i>
	<i>Bemisia tabaci</i>	
148.	<i>Solanum villosum</i>	
	<i>Bemisia tabaci</i> , <i>Trialeurodes abutiloneus</i>	
149.	<i>Solanum sp.</i>	
	<i>Bemisia tabaci</i> , <i>Trialeurodes abutiloneus</i>	
150.	<i>Sonchus oleraceus</i>	
	<i>Bemisia tabaci</i> , <i>Trialeurodes abutiloneus</i> ,	
	<i>T. vaporiorum</i>	
151.	<i>Stachys floridensis</i>	
	<i>Bemisia tabaci</i>	
152.	<i>Tabebuia glomerata</i>	
	<i>Aleurotrachelus trachoides</i>	
153.	<i>Terminalia catappa</i>	
	<i>Aleurodicus dispersus</i>	
154.	<i>Tithonia rotundifolia</i>	
	<i>Bemisia tabaci</i> , <i>Trialeurodes abutiloneus</i>	
155.	<i>Trifolium resupinatum</i>	
	<i>Bemisia tabaci</i>	
156.	<i>Trifolium sp.</i>	
	<i>Bemisia tabaci</i>	
157.	<i>Urena lobata</i>	
	<i>Bemisia tabaci</i> , <i>Trialeurodes abutiloneus</i>	
158.	<i>Urtica sp.</i>	
	<i>Trialeurodes abutiloneus</i>	
159.	<i>Vaccinium sp.</i>	
	<i>Aleuroplatus vaccinii</i>	
160.	<i>Verbena scabra</i>	
	<i>Aleurotrachelus sp.</i>	
161.	<i>Viburnum sp.</i>	
	<i>Dialeurodes citri</i>	
162.	<i>Viburnum sp.</i>	
	<i>Dialeurodes citri</i>	
163.	<i>Vitis sp.</i>	
	<i>Bemisia tabaci</i>	
164.	<i>Xanthosoma sagittifolium</i>	
	<i>Aleuroglandulus malangae</i>	
165.	<i>Xanthium sp.</i>	
	<i>Trialeurodes vaporiorum</i>	
166.	<i>Yocora sp.</i>	
	aleyrodid	
167.	<i>Youngia japonica</i>	
	<i>Bemisia tabaci</i> , <i>Trialeurodes abutiloneus</i>	
168.	Indetermined whitefly host	
	<i>Aleurodicus dispersus</i> <i>Aleurothrixus</i> <i>fluccosus</i> , <i>Aleurotrachelus trachoides</i> , <i>Bemisia tabaci</i> , <i>Dialeurodes kirkaldyi</i> , <i>Tetraleurodes acaciae</i> , <i>Trialeurodes</i> <i>abutiloneus</i> , <i>T. vaporiorum</i> , <i>Trialeurodes sp.</i>	

APPENDIX C
Measurements and Statistics for New Species

<i>Encyrtus tenuiculus</i>													
	Body	Head	Body + Head	Radicle	Scape	Pedicel	F1	F2	F3	F4	F5	F6	
Holotype	0.430	0.149	0.560	0.030	0.064	0.038	0.028	0.036	0.046	0.046	0.050	0.050	0.058
Mean	0.452	0.149	0.601	0.034	0.068	0.039	0.029	0.038	0.047	0.050	0.050	0.058	
St. Error	0.02244894	0.00257682	0.02322585	0.004	0.00271293	0.0008	0.0004899	0.00074833	0.0006	0.00172047	0.00009788	0.0004	
Median	0.430	0.150	0.560	0.030	0.064	0.038	0.030	0.036	0.046	0.046	0.050	0.058	
St. Dev.	0.0501898	0.00576184	0.05193457	0.00894427	0.0060663	0.00178885	0.00109545	0.00167332	0.00178885	0.00384708	0.00219089	0.00089443	
Minimum	0.400	0.140	0.550	0.030	0.060	0.038	0.026	0.036	0.046	0.046	0.048	0.056	
Maximum	0.530	0.158	0.688	0.050	0.098	0.042	0.030	0.040	0.050	0.056	0.054	0.058	

<i>Encyrtus pseudoschizus</i>													
	Body	Head	Body + Head	Radicle	Scape	Pedicel	F1	F2	F3	F4	F5	F6	
Mean	0.507	0.160	0.667	0.027	0.070	0.033	0.034	0.035	0.036	0.037	0.037	0.048	
St. Error	0.02848001	0.0141882	0.04265104	0.00066667	0.00466667	0.00333333	0.002	0.00133333	0	0.00066667	0.00066667	0	
Median	0.530	0.170	0.700	0.028	0.080	0.036	0.036	0.036	0.036	0.036	0.038	0.048	
St. Dev.	0.04822683	0.02457641	0.07387377	0.0011547	0.0090829	0.0057795	0.0031641	0.0023294	0	0.0011547	0.0011547	0	
Minimum	0.450	0.132	0.582	0.026	0.070	0.026	0.030	0.032	0.036	0.036	0.036	0.048	
Maximum	0.540	0.178	0.718	0.028	0.086	0.036	0.036	0.036	0.036	0.038	0.038	0.048	

<i>Encyrtus polemistis</i>													
	Body	Head	Body + Head	Radicle	Scape	Pedicel	F1	F2	F3	F4	F5	F6	
Holotype	0.530	0.014	0.670	0.030	0.068	0.032	0.032	0.040	0.040	0.042	0.046	0.054	
Mean	0.518	0.1556	0.6718	0.0278	0.0872	0.0348	0.03	0.0388	0.0392	0.0404	0.0432	0.0524	
St. Error	0.01720465	0.01441368	0.02944416	0.00193907	0.0010198	0.00215407	0.00109549	0.00165472	0.0008	0.00172047	0.00149666	0.00172047	
Median	0.52	0.154	0.674	0.03	0.088	0.032	0.03	0.038	0.04	0.042	0.044	0.054	
St. Dev.	0.03847077	0.03223042	0.0658382	0.0043356	0.00226035	0.00481664	0.00244948	0.00414728	0.00178885	0.00384708	0.00334664	0.00384708	
Minimum	0.450	0.114	0.564	0.020	0.084	0.030	0.026	0.030	0.036	0.034	0.038	0.048	
Maximum	0.550	0.200	0.730	0.030	0.090	0.040	0.032	0.040	0.040	0.044	0.046	0.058	

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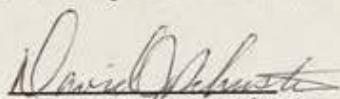
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BIOGRAPHICAL SKETCH

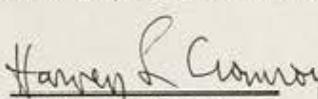
Gregory Allyn Evans was born on July 18, 1956 in Cheverly, Maryland. He entered the University of Maryland in 1974 and graduated with a Bachelor of Science degree in conservation and resource development in 1979. He joined the Peace Corps in 1981 where he spent two years working on a survey of agricultural pests in western Honduras. After returning to the United States in 1983, he worked as a field scout on soybeans, corn and small grains on the Maryland eastern shore. In 1984, he started working as a laboratory technician for the Systematic Entomology Laboratory in Beltsville, Maryland and returned to Honduras in 1987, to do a survey of the plant feeding mites of Honduras. He entered the University of Florida in 1988 and completed his Master of Science degree on the Tenuipalpidae of Honduras. He is married to Blanca Eduviges; they have four children, Luis, Roberto, Michael and Joshua.

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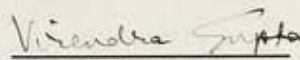
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Professor of Entomology and Nematology

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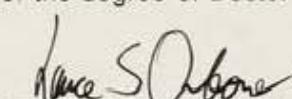
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Professor of Entomology and Nematology

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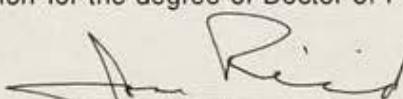
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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



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