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A survey of parasitoids of Bemisia spp. whiteflies in Florida, the Caribbean, and Central and South America

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Abstract. Wild and cultivated plants were surveyed in Florida, the Caribbean, and Latin America for parasitoids of *Bemisia* spp. whiteflies. Foliage samples containing late instar *Bemisia* nymphs were collected and held in the laboratory for emergence of adult parasitoids. Florida collections were made weekly, biweekly or monthly depending upon the time of year and location. Samples also were collected on an irregular basis in Caribbean and Latin American countries including Brazil, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Grenada, Guadeloupe, Guatemala, Honduras, Jamaica, Mexico, Puerto Rico and Venezuela. At least 20 species of parasitoids and one species of hyperparasitoid were reared from *Bemisia*. *Encarsia pergandiella* Howard (which may be a complex of species including the sympatric species *E. tabacivora* Viggiani), *E. nigricephala* Dozier and *Eretmocerus* spp. were the most abundant parasitoids, accounting for 59%, 16% and 13%, respectively, of the total reared from *Bemisia*. *Encarsia meritoria* Gahan, which is a complex of species but which may be mostly *E. hispida* De Santis in the New World, was rarely collected in Florida but was abundant at some sites in the Caribbean and Latin America.

1. Introduction

The sweetpotato whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae), is an important pest of numerous agronomic, horticultural and ornamental crops and is widely distributed throughout the tropics (CAB Institute of Entomology, 1986). An outbreak of the silverleaf whitefly (*B. argentifolii* Bellows & Perring), initially attributed to *B. tabaci*, began in 1986 in Florida. Similar outbreaks subsequently were observed in Central and South America and the Caribbean. This new whitefly was associated with physiological disorders of vegetables and ornamentals (Schuster *et al.*, 1996) and transmitted plant viruses of tomato (Polston *et al.*, 1993, 1994) and bean (Blair *et al.*, 1995). Direct and indirect losses in Florida alone in 1991 amounted to about $140 million (Schuster, unpublished data). To avoid such losses, insecticides are often applied frequently and preventatively to manage *Bemisia* populations; however, this approach can lead to the development of insecticide resistance in whiteflies (Prabhaker *et al.*, 1985; Dittrich *et al.*, 1990; Cahill *et al.*, 1995). Integrating biological biological control into management programmes could provide long-term, stable control of *Bemisia* spp. whiteflies. Little is known regarding the parasitoids of *Bemisia* in the New World. *Encarsia formosa* Gahan, *En. meritoria Gahan* (= *En. hispida* De Santis?), *Eretmocerus haldemani* Howard, and *Er. eremicus* Rose & Zolnerowich (= *Er. californicus* Howard of author, misidentified) (Rose and Zolnerowich 1997) were found to attack *B. tabaci* in California (Gerling 1966, 1967). As the first step in evaluating the potential of biological control in the Neotropics, a survey was undertaken to determine the parasitoids attacking *Bemisia* spp. on wild and cultivated host plants in Florida, Central and South America and the Caribbean.

2. Materials and methods

Collection of foliage samples was begun in 1988 in the Gainesville, Florida area following reports of a heavy infestation of the silverleaf whitefly in soybean plots on the University of Florida campus. In addition to sampling soybean, weeds growing in the crop or nearby were also examined for whiteflies. Collections were made weekly or biweekly from Sept. 1988 to Nov. 1991 and monthly from May to Oct. 1992.

An expanded sampling effort was initiated at various sites around Florida (figure 1). At least two sampling sites were established in undisturbed areas near vegetable crops (primarily tomato) at Bradenton, Homestead, Immokalee, Parrish, and Ruskin. Each site was sampled weekly, biweekly or monthly depending on the time of year and location. The Bradenton, Immokalee, Parrish, and Ruskin sites were sampled biweekly from July 1989 to July 1990. At Homestead, collections usually were made monthly between Oct. 1989 and Oct. 1990 except for May to July 1990 when they were made weekly. Plants also were sampled in May and June, 1992. All sites also were sampled biweekly from January to May 1994.

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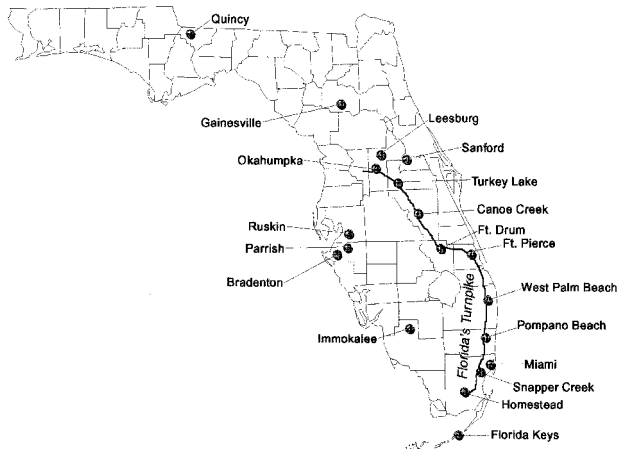

Figure 1. Sites in Florida, USA sampled for parasitoids of Bemisia *spp. whiteflies.*

To collect samples, progressively older leaves of known weed hosts of *B. tabaci* were examined for the presence of nymphs. For those hosts which were infested, a sample of no more than 10 leaves with late stage nymphs or pupae present was collected. When possible, similar collections of *Bemisia*-infested foliage were made from adjacent or nearby cultivated crops.

In March 1990, sampling sites of about 40 plants each of collards, *Brassica oleracea* L., and okra, *Hibiscus esculentus* L., were established at University of Florida Research and Education Centers at Bradenton, Homestead, Immokalee, Leesburg, and Sanford. Plants were inspected weekly or biweekly from May to July 1990 or until March 1991 at Sanford. If *Bemisia*-infested leaves of either crop were present, up to ten leaves were collected.

Sampling sites were established along the Florida Turnpike at Okahumpka, Turkey Lake, Canoe Creek, Fort Pierce, Fort Drum, West Palm Beach, Pampano Beach, Snapper Creek, and Miami, and on highway US 1 in the Florida Keys. Foliage samples of *Bemisia*-infested weeds and ornamental plantings were collected monthly from January 1990 to August 1992.

A collecting trip to Honduras and Costa Rica was accomplished in early February 1990 and to Puerto Rico in May 1990, and arrangements to receive additional specimens from those countries were made. In addition, material was collected in Brazil, Colombia, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Mexico, Guadeloupe, Venezuela, Puerto Rico, and Jamaica by individuals visiting those countries for other investigations.

All foliage samples were held in the laboratory, generally in cylindrical paper cans (The Fonda Group, Inc., Union, NJ 07083 USA), until adult whiteflies and parasitoids had emerged and died. Foreign collections were handled in the quarantine facility at the Florida Department of Agriculture and Consumer Services, Gainesville, FL, USA. The parasitoid adults were separated, counted, and identified. Representative adults of each parasitoid species from each host from each location were mounted on glass microscope slides to confirm parasitoid identifications and to preserve a collection of voucher specimens. Voucher specimens are housed at the Florida State Collection of Arthropods, Florida Department of Agriculture and Consumer Services, Gainesville, FL, USA.

3. Results and discussion

At least 20 species of parasitoids (all Aphelinidae except for the platygasterid, *Amitus bennetti* Viggiani & Evans, and the encyrtid, *Metaphycus*) and one species of hyperparasitoid (*Signiphora aleyrodis* Ashmead: Signiphoridae) were reared from *Bemisia* in the Caribbean, Latin America, and Florida (tables 1 and 2). As noted by Polaszek *et al.* (1992), *Metaphycus* had not been recorded previously from Aleyrodidae, but it is unlikely that they were hyperparasitoids since hyperparasitism by males is not known in the genus (Noyes, personal communication) and because all specimens were females. The number of *Eretmocerus* species has not yet been determined. *Encarsia pergandiella* Howard is listed as a complex because the synonymy of *E. pergandiella* and the sympatric species *E. tabacivora* Viggiani (Polaszek *et al.*, 1992; Schauff *et al.*, 1996) is considered incorrect (Woolley and Johnson, personal communication). *E. meritoria* Gahan is a complex of *E. haitiensis* Dozier, *E. brasiliensis* (Hempel) and *E. hispida* De Santis. The latter species was listed as a synonym with *E. meritoria* by Viggiani (1989) but was removed from synonymy by Polaszek *et al.* (1992); however, Schauff *et al.* (1996) later resurrected the synonymy. Current research indicates that the majority of *E. meritoria* complex specimens reared from *Bemisia* spp. in the New World are probably *E. hispida* (Polaszek and Evans, personal communication). The *E. strenua* group contains at least 11 species (Evans, 1993) with at least six species known to attack *B. tabaci: E. strenua* (Silvestri), *E. transvena* (Timberlake), species belonging to the *citrella* species complex [*E. citrella* (Howard), *E. paracitrella* Evans & Polaszek, *E. pseudocitrella* Evans & Polaszek] (Evans and Polaszek, 1997), and at least one undescribed species introduced into the USA from India (Nguyen and Bennett, 1995).

E. pergandiella complex, *Eretmocerus* spp., and *E. meritoria* complex were the most abundant parasitoids attacking *Bemisia* in the Neotropics, excluding Florida, accounting for about 39%, 16% and 15%, respectively, of the 7600 parasitoid specimens collected (table 1). However, other species were more abundant in some countries, including *E. lutea* in Brazil, *E. formosa* and *E. transvena* in Costa Rica, *E. transvena* in the Dominican Republic, *E. nigricephala* in Grenada and Jamaica, *E. strenua* group in Guatemala, and *E. quaintancei* in Jamaica. These variations may be artifacts of infrequent or seasonal sampling because, with the exception of Brazil, relatively few specimens were obtained from these countries and collections were not evenly distributed temporally.

E. pergandiella complex, *E. nigricephala*, and *Eretmocerus* spp. were the most abundant parasitoids in Florida accounting for about 62%, 17% and 12%, respectively, of the 49 000 parasitoid specimens collected (table 2). Unlike many countries in the Caribbean and Latin America, specimens in the *E. meritoria* complex were rarely collected in Florida. Conversely, *E. nigricephala* was more abundant in Florida than in most other countries sampled. *E. luteola* was more abundant at sample sites along the Florida Turnpike. In 1990–91, *A. bennetti* was introduced into the state from Puerto Rico, but

Table 1. Distribution and relative abundance (% of the total for each country) of hymenopterous parasitoids of Bemisia *spp. in the Caribbean and Latin America*[a]

Parasitoid spp.	BRA	COL	CTR	DMR	ECU	ELS	GRE	GAU	GTM	HON	JAM	MEX	PTR	VEN	Total
Amitus bennetti Viggiani & Evans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	2.2	0.0	0.6
Encarsia citrella (Howard)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.1	< 0.1
E. desantisi Viggiani	0.3	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.1	0.2
E. formosa Gahan	0.9	0.0	27.5	13.6	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	6.4	0.1	1.9
E. lanceolata Evans & Polaszek	0.1	0.0	0.0	0.0	38.9	0.0	0.0	0.0	0.0	0.0	0.0	2.1	1.0	0.0	0.4
E. lutea (Masi)	25.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3
E. luteola Howard	0.3	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	4.1	0.0	3.5	2.1	0.3	0.9
E. meritoria complex	9.8	11.9	37.5	18.5	0.0	0.0	0.0	0.0	0.0	9.3	10.8	9.1	8.8	22.2	14.5
E. nigricephala Dozier	7.0	4.8	0.0	6.2	0.0	0.0	88.9	23.5	21.7	9.7	51.4	3.5	1.2	3.7	5.0
E. paracitrella Evans & Polaszek	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	0.1
E. pergandiella complex	16.0	19.0	0.0	24.7	61.1	100.0	11.1	48.9	30.4	27.2	18.9	21.7	71.5	43.4	38.5
E. polaszeki Evans	11.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9
E. porteri (Mercet)	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	0.0	0.0	0.0	0.0	1.1
E. pseudocitrella Evans & Polaszek	0.1	0.0	2.5	0.0	0.0	0.0	0.0	0.0	8.7	1.1	0.0	0.0	0.0	0.0	0.1
E. quaintancei Howard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	18.9	2.1	0.3	0.1	0.2
E. strenua group	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.1	0.0	0.0	0.0	0.0	< 0.1	4.2
E. transvena (Timberlake)	0.1	0.0	12.5	25.9	0.0	0.0	0.0	0.0	0.0	20.1	0.0	1.4	0.0	0.0	1.1
Encarsia sp.	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	1.4	0.6	0.1	0.6
Eretmocerus spp.	10.4	59.5	17.5	4.9	0.0	0.0	0.0	5.5	0.0	15.3	0.0	41.3	4.6	26.5	16.3
Metaphycus sp. n.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	< 0.1
Signiphora aleyrodis Ashmead	1.3	2.4	2.5	2.5	0.0	0.0	0.0	12.1	0.0	0.7	0.0	0.0	1.4	3.3	2.0
No. parasitoids	2471	42	40	81	18	10	18	210	23	268	37	143	1531	2925	7607

[a]BRA=Brazil, COL=Columbia, CTR=Costa Rica, DMR=Dominican Republic, ECU=Ecuador, ELS=El Salvador, GRE=Grenada, GAU=Guadeloupe, GTM=Guatemala, HON=Honduras, JAM=Jamaica, MEX=Mexico, PTR=Puerto Rico and VEN=Venezuela.

Table 2. Distribution and relative abundance (% of the total for each location) of hymenopterous parasitoids of Bemisia *spp. in Florida*[a]

Parasitioid spp.	BRA	CNC	FLK	FTD	FTP	GNV	HOM	IMM	LEE	MIA	OKA	PAR	PMB	QCY	RUS	SAN	SNC	TKL	WPB	Total
Amitus bennetti	< 0.1	0.0	0.0	0.0	0.0	< 0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 0.1
Encarsia formosa	0.0	0.0	0.0	0.0	< 0.1	< 0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	< 0.1
E. lanceolata	0.0	0.0	0.0	0.0	0.0	< 0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	< 0.1
E. luteola	0.7	14.9	50.0	29.9	17.3	0.8	2.4	0.2	0.9	4.9	21.9	5.0	59.2	0.9	0.0	0.4	37.6	10.3	29.8	5.4
E. meritoria complex	0.0	0.0	0.3	0.0	0.1	< 0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	1.1	< 0.1
E. nigricephala	17.0	25.1	8.1	19.1	4.2	22.9	3.4	25.3	3.3	7.6	17.3	7.7	0.7	24.8	12.5	35.6	1.8	6.4	1.9	17.4
E. pergandiella complex	71.0	49.3	7.1	34.9	36.2	62.2	85.5	72.1	49.4	49.7	58.3	80.3	21.5	8.8	65.4	47.9	45.1	47.6	61.7	61.7
E. pseudocitrella	0.0	0.0	0.0	0.0	0.0	< 0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 0.1
E. quaintancei	0.1	1.6	0.0	0.0	7.5	< 0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	30.3	0.1	1.0
E. strenua group	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.1	0.0	0.0	0.0	17.7	0.0	0.0	0.0	0.0	0.4	0.6
E. transvena	< 0.1	0.0	29.5	11.3	0.8	0.6	0.0	0.2	0.0	18.8	0.0	0.0	12.6	0.0	0.4	0.0	1.4	0.0	2.5	1.6
Encarsia sp.	< 0.1	1.4	1.9	0.0	1.1	0.3	0.1	0.0	0.0	0.9	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2
Eretmocerus spp.	11.0	7.7	2.2	4.7	32.8	12.4	8.5	1.7	46.4	17.6	1.8	7.0	5.9	47.8	21.7	16.0	14.0	5.4	2.2	11.9
Signiphora aleyrodis	< 0.1	0.0	0.9	0.0	0.0	< 0.1	0.0	0.6	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
No. parasitoids	13288	442	322	679	1315	18710	2732	2257	330	1599	133	226	272	2244	981	1226	981	1226	718	49258

[a]BRA=Bradenton, CNC=Canoe Creek, FLK=Florida Keys, FTD=Fort Drum, FTP=Fort Pierce, GNV=Gainesville, HOM=Homestead, IMM=Immokalee, LEE=Leesburg, MIA=Miami, OKA=Okahumpka, PAR=Parrish, PMB=Pompano Beach, QCY=Quincy, RUS=Ruskin, SAN=Sanford, SNC=Snapper Creek, TKL=Turkey Lake and WPB=West Palm Beach.

was recovered in low numbers in only four counties of 11 into which it was released (Nguyen and Bennett, 1995). *E. transvena* tended to occur more frequently at southern sites than at northern sites.

Data were summarized over three geographical areas: north central (Gainesville), west central (Bradenton, Parrish and Ruskin), and southwestern (Immokalee). The data were averaged over the number of adults reared per sample per month, and only months with two or more samples were included. The averages may be biased due to the variability in the number of individuals reared on certain host plants at certain times of the year and the availability of hosts during the year. Nevertheless, the data suggest that all three of the most abundant parasitoids/parasitoid complex are present year round in all three regions, but that numbers generally were low from January to April (figures 2 and 3). *Eretmocerus* spp. were present in very low numbers (figure 3) in southwest Florida.

The data indicate that a large number of parasitoid species attack *Bemisia* in Florida, the Caribbean, and Latin America; however, relatively few species/species complexes predominate. *E. pergandiella* complex was the most abundant (59%) followed by *E. nigricephala* (16%), and *Eretmocerus* spp. (13%). Stansly *et al.* (1997) also found these three species plus *E. transvena* to be the most abundant on eight crop and ten weed species in southwest Florida. In north central Florida, *E. nigricephala* was the most abundant parasitoid reared from peanuts, while *E. pergandiella*, *E. transvena*, and *Eretmocerus* sp. were less abundant (McAuslane *et al.*, 1993, 1994).

The large, naturally occurring complex of parasitoids attacking *Bemisia* in Florida can cause high levels of mortality of *B. argentifolii* in the absence of conventional insecticides. Apparent parasitism of *B. argentifolii* at an organic farm in southwest Florida reached 80% on tomato and > 80% on egg plant (Brewster *et al.*, 1997; Stansly *et al.*, 1997). In west central Florida, combined mortality of the whitefly due to parasitism and predation on weeds on tomato field perimeters ranged from 40 to 90% in 1991 and 10 to 70% in 1992 (Schuster *et al.*, 1992). Up to 100% of *B. argentifolii* nymphs were parasitized on nonspayed peanuts in north central Florida (McAuslane *et al.*, 1993, 1994). Thus, conserving the large complement of natural enemies through the judicious use of selective insecticides can result in an important contribution of biological control in integrated pest management programmes.

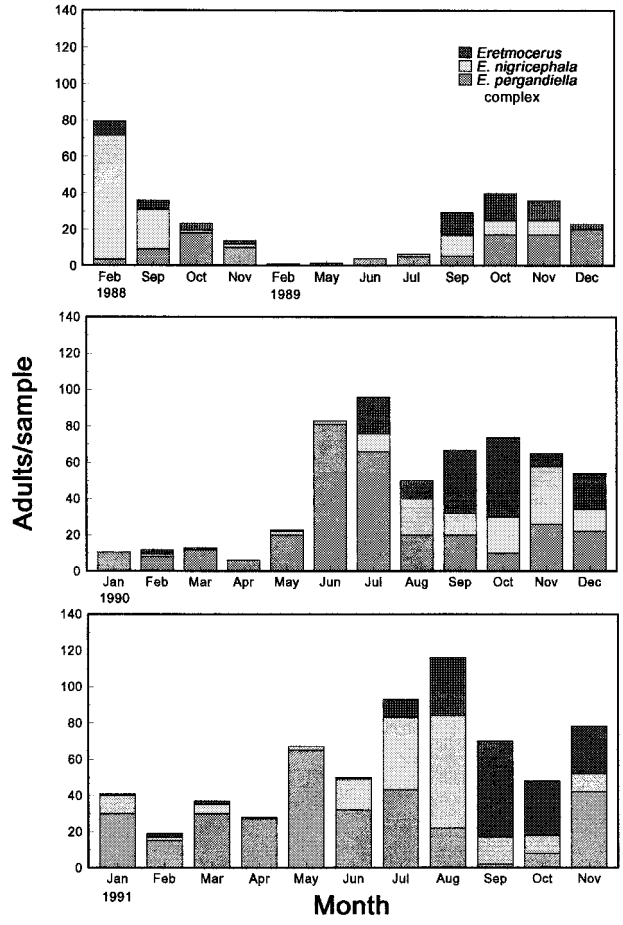

Figure 2. Seasonality of the three most abundant parasitoid species/species complex reared from Bemisia *spp. on wild and cultivated hosts at Gainesville (Alachua County), Florida, USA.*

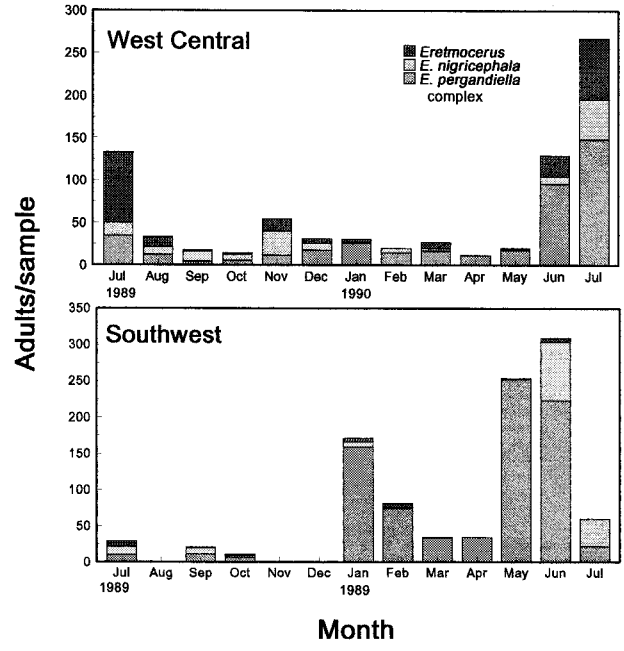

Figure 3. Seasonality of the three most abundant parasitoid species/species complex reared from Bemisia *spp. on wild and cultivated hosts in west Central (Manatee and Hillsborough Counties) and southwest (Collier County) Florida, USA.*

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