

## **An Updated List of Parasitoid Hymenoptera Reared from the *Bemisia tabaci* Species Complex (Hemiptera: Aleyrodidae)**

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# An updated list of parasitoid Hymenoptera reared from the *Bemisia tabaci* species complex (Hemiptera: Aleyrodidae)

Zachary Lahey\* and Philip Stansly

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## Abstract

An updated list to the world fauna of parasitoid Hymenoptera reared from members in the *Bemisia tabaci* species complex (Hemiptera: Aleyrodidae) is provided. In total, 112 parasitoid species in 5 families and 7 genera are tabulated along with their global distributions. Pertinent references are given to aid in the accurate identification of these minute insects. We also reviewed published host-genera associations and consider some dubious, possibly due to contamination of rearing vessels with non-target insects or to misidentification of the host whitefly or parasitoid species.

Key Words: Aphelinidae; Azotidae; Encyrtidae; Signiphoridae; Platygastriidae; *Encarsia*; *Eretmocerus*

## Resumen

Se proporciona una lista actualizada de la fauna mundial de parasitoides himenópteros criados de los miembros del complejo de especies *Bemisia tabaci* (Hemiptera: Aleyrodidae). Se tabulan un total de 112 especies de parasitoides en cinco familias y siete géneros junto con sus distribuciones globales. Se dan referencias pertinentes para ayudar en la identificación correcta de estos diminutos insectos. Revisamos también las asociaciones publicadas de género con sus huéspedes. Algunas de ellos parece ser erróneas, debido posiblemente a la contaminación de los envases de crianza con insectos lejano o de una identificación errónea de la mosca blanca de acogida o especies de parasitoides.

Palabras Clave: Aphelinidae; Azotidae; Encyrtidae; Signiphoridae; Platygastriidae; *Encarsia*; *Eretmocerus*

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The whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae), is considered to represent a cryptic species complex of global economic importance (De Barro et al. 2011; De Barro 2012). Two putative species are internationally distributed, Middle East-Asia Minor 1 (MEAM1; formerly biotype B or *Bemisia argentifolii* Bellows & Perring) and Mediterranean (MED; formerly biotype Q, and a genetic match to the original specimens collected by P. Gennadius) (Tay et al. 2012). Both have become notorious for their roles as the vectors of plant viruses to economically important crops (Lapidot & Polston 2010; Polston et al. 2014) and for their ability to develop resistance to a number of insecticides (Horowitz et al. 2005; Castle et al. 2010).

Since the initial invasion and spread of MEAM1 throughout the United States there has been a strong focus on the use of biological control agents to combat *Bemisia* infestations both in open-field and protected environments (Nguyen & Bennett 1995; Gould et al. 2008). The natural enemies of whiteflies include predators, parasitoids, and fungi. Arguably, the most important of these are the parasitoid Hymenoptera due to the relative ease of culture in the laboratory and the narrow host range of many species (Goolsby et al. 2005; De Barro & Coombs 2009; Pickett et al. 2013). The purpose of this paper is to provide a list of the parasitoid wasps reported to attack members of the *B. tabaci* species complex (Table 1).

All parasitoids known to attack *B. tabaci* whiteflies are hymenopteran wasps distributed between 5 families: Aphelinidae, Az-

otidae, Encyrtidae, Signiphoridae (Chalcidoidea), and Platygastriidae (Platygastridae). In addition to named species, there exist numerous published records of undescribed or otherwise unidentified species in particular genera parasitizing a member of the *B. tabaci* species complex. These are excluded from the list herein because they potentially represent nominal species already listed, with exception to the genus *Metaphycus* Mercet (Encyrtidae), where accurate rearing records exist but no specific entities have been formally characterized (Evans 1993). There also are certain genera with host records that include a *B. tabaci* species complex member that is unlikely given known host-associations. We discuss these taxa and our rationale for their exclusion in detail below.

The following table compiles information presented in previously published parasitoid lists while adding recent information gleaned from the literature. The number of parasitoid species reported from the *B. tabaci* species complex has increased significantly since 18 parasitoid species were first tabulated by Greathead & Bennett (1981). Gerling (1986) included 19 species in his review, omitting several from Greathead & Bennett (1981), while including new taxa, many of genus rank. Gerling et al. (2001) increased that number to 56, and Arnó et al. (2010) added an additional 20 species (all *Encarsia* and *Eretmocerus*) not included, reported, or described since Gerling et al. (2001). The current work continues on this theme bringing the total to 112 species with the expectation that this number will continue to grow as

**Table 1.** Parasitoid Hymenoptera reportedly reared from the *Bemisia tabaci* species complex.

Taxa	Authority	Distribution	Reference	
Aphelinidae				
<i>Cales</i>	<i>noacki</i>	Howard	2, 3, 4	Guastella et al. 2014
<i>Encarsia</i>	<i>abundantia</i>	Chou & Su	5, 6	Li et al. 2011
	<i>acaudaleyrodia</i>	Hayat	3, 6	Polaszek et al. 1999
	<i>accenta</i>	Schmidt & Naumann	7	Schmidt et al. 2001
	<i>adusta</i>	Schmidt & Naumann	7	Schmidt et al. 2001
	<i>albiscutellum</i>	(Girault)	5, 7	Li et al. 2011
	<i>aleurochitonis</i>	(Mercet)	3	Luo et al. 1989
	<i>aleurothrix</i>	Evans & Polaszek	2	de Oliveira et al. 2003
	<i>ancistrocera</i>	Huang & Polaszek	5	Li et al. 2011
	<i>aseta</i>	Hayat & Polaszek	5, 6, 9	Shih et al. 2008
	<i>aspidioticola</i>	(Mercet)	3	Greathead & Bennett 1981
	<i>asterobemisiae</i>	Viggiani & Mazzone	3	Evans 2007
	<i>azimi</i>	Hayat	3, 5, 6	Schmidt et al. 2001
	<i>bennetti</i>	Hayat	5, 6	Li et al. 2011
	<i>Encarsia</i>	<i>bimaculata</i>	Heraty & Polaszek	1, 2, 3, 4, 5, 6, 7
<i>bothrocera</i>		Huang & Polaszek	5	Li et al. 2011
<i>brasiliensis</i>		(Hempel)	1, 2, 3, 4, 7	Polaszek et al. 1992
<i>brevivena</i>		Hayat	6	Hayat 1989
<i>californica</i>		Polaszek	1	Polaszek et al. 2004
<i>cibcensis</i>		Lopez-Avila	3, 5, 6, 7	Lopez-Avila 1987
<i>citrella</i>		(Howard)	1, 2	Evans & Polaszek 1997
<i>citri</i>		(Ishii)	5	Kajita 2000
<i>collecta</i>		Chou & Su	5	Li et al. 2011
<i>coquilletti</i>		Howard	1, 2	Hoelmer & Goolsby, 2002
<i>davidi</i>		Viggiani & Mazzone	3, 4	Hernandez et al. 2003
<i>desantisi</i>		Viggiani	2	Polaszek et al. 1992
<i>duorunga</i>		Hayat	5, 6	Hayat 1989
<i>echinocera</i>		Huang & Polaszek	5	Li et al. 2011
<i>Encarsia</i>	<i>elegans</i>	Masi	3, 5, 6	Abd-Rabou 1998
	<i>formosa</i>	Gahan	WW	De Barro et al. 2000
	<i>fujianensis</i>	Huang & Polaszek	5	Li et al. 2011
	<i>fuzhouensis</i>	Huang & Polaszek	5	Shih et al. 2008
	<i>gerlingi</i>	Viggiani	3, 5	Li et al. 2011
	<i>guadeloupae</i>	Viggiani	1, 2, 3, 4, 6, 7, 9	Schmidt et al. 2001
	<i>hamata</i>	Huang & Polaszek	5	Li et al. 2011
	<i>hamoni</i>	Evans & Polaszek	1, 2	Evans & Polaszek 1998
	<i>inaron</i>	(Walker)	1, 2, 3, 4, 5, 6, 7	Manzari et al. 2002
	<i>ishii</i>	(Silvestri)	5	Li et al. 2011
	<i>japonica</i>	Viggiani	5	Kajita 2000
	<i>lahorensis</i>	(Howard)	1, 3, 5, 6	Li et al. 2011
	<i>lanceolata</i>	Evans & Polaszek	1, 2	Evans & Polaszek 1997
	<i>longicauda</i>	Hayat	5, 6	Li et al. 2011
<i>Encarsia</i>	<i>longifasciata</i>	Subba Rao	5, 6, 7	Pedata & Polaszek 2003
	<i>longivalvula</i>	Viggiani	5, 6	Schmidt & Polaszek 2007
	<i>lounsburyi</i>	(Berlese & Paoli)	1, 2, 3, 4, 5, 6, 7, 8	Li et al. 2011
	<i>lutea</i>	(Masi)	1, 2, 3, 4, 5, 6, 7, 8	Folytn & Gerling 1985
	<i>luteola</i>	Howard	1, 2, 3, 5	Castineiras 1995
	<i>macoensis</i>	Abd-Rabou & Ghahari	3	Abd-Rabou & Ghahari 2007
	<i>magnivena</i>	Huang & Polaszek	5	Li et al. 2011
	<i>melanostoma</i>	Polaszek & Hernandez	3	Hernández-Suárez et al. 2003
	<i>merceti</i>	Silvestri	2, 5, 6, 7	Li et al. 2011
	<i>meritoria</i>	Gahan	1, 2	Hoelmer & Goolsby 2002
	<i>mineoi</i>	Viggiani	3, 4, 7	Polaszek et al. 1999
	<i>mohyuddini</i>	Shafee & Rizvi	3, 5, 6	Shafee & Rizvi 1982
	<i>neoporteri</i>	Myartseva & Evans	1, 2	Myartseva & Evans 2007
	<i>nigricephala</i>	Dozier	1, 2, 4, 8	Stansly et al. 1997
<i>Encarsia</i>	<i>nipponica</i>	Silvestri	5, 9	Li et al. 2011
	<i>noahi</i>	Polaszek & Hernandez	3	Hernández-Suárez et al. 2003

**Table 1. (Continued)** Parasitoid Hymenoptera reportedly reared from the *Bemisia tabaci* species complex.

Taxa	Authority	Distribution	Reference
<i>oakeyensis</i>	Schmidt & Naumann	7	Schmidt et al. 2001
<i>obtusiclava</i>	Hayat	5	Shih et al. 2008
<i>opulenta</i>	(Silvestri)	5, 6	Li et al. 2011
<i>paracitrella</i>	Evans & Polaszek	2	Evans & Polaszek 1997
<i>parvella</i>	Silvestri	4	Sauvion et al. 2000
<i>perflava</i>	Hayat	5, 6	Evans 2007
<i>pergandiella</i>	Howard	1, 2, 3, 7	Argov & Rössler 1988; Liu & Stansly 1996
<i>perplexa</i>	Huang & Polaszek	1, 2, 5, 6	Li et al. 2011
<i>polaszeki</i>	Evans	2	Evans 1997
<i>porteri</i>	(Mercet)	2	Viscarret et al. 2000
<i>protransvena</i>	Viggiani	1, 2, 3, 5, 8, 9	Huang & Polaszek 1998
<i>pseudocitrella</i>	Evans & Polaszek	1, 2	Evans & Polaszek 1997
<i>Encarsia</i>			
<i>quaintancei</i>	Howard	1, 2	Stansly et al. 1997
<i>reticulata</i>	Rivnay	3	Rivnay & Gerling 1987
<i>scapeata</i>	Rivnay	3	Gerling et al. 2009
<i>smithi</i>	(Silvestri)	1, 5, 6, 7	Polaszek et al. 1992
<i>sophia</i>	(Girault & Dodd)	1, 2, 3, 4, 5, 6, 7, 9	Heraty & Polaszek 2000
<i>strenua</i>	(Silvestri)	3, 5, 6	Shih et al. 2008
<i>synaptocera</i>	Huang & Polaszek	5	Shih et al. 2008
<i>tabacivora</i>	Viggiani	1, 2	Evans & Serra 2002
<i>thoreauini</i>	(Girault)	7	Schmidt & Polaszek 2007
<i>tricolor</i>	Förster	3, 4	Hernández-Suárez et al. 2003
<i>tristis</i>	(Zehntner)	4, 5, 6, 7	Li et al. 2011
<i>variegata</i>	Howard	1, 2	Myartseva & Evans 2007
<i>Eretmocerus</i>			
<i>aegypticus</i>	Evans & Abd-Rabou	3	Abd-Rabou & Evans 2002
<i>diversiciliatus</i>	Silvestri	3, 4	Abd-Rabou 1998
<i>Eretmocerus</i>			
<i>emiratus</i>	Zolnerowich & Rose	1, 4	Zolnerowich & Rose 1998
<i>eremicus</i>	Rose & Zolnerowich	1, 3	Rose & Zolnerowich 1997a
<i>evansi</i>	Myartseva	2	Myartseva 2006a
<i>furushashii</i>	Rose & Zolnerowich	1, 5	Li et al. 2011
<i>gunturiensis</i>	Hayat	6	Li et al. 2011
<i>hayati</i>	Zolnerowich & Rose	1, 6, 7	Zolnerowich & Rose 1998
<i>joeballi</i>	Rose & Zolnerowich	1	Rose & Zolnerowich 1997a
<i>longiscapus</i>	Hayat	3	Li et al. 2011
<i>melanoscutus</i>	Zolnerowich & Rose	1, 6	Zolnerowich & Rose 1998
<i>mundus</i>	Mercet	1, 3, 4, 5, 6, 7	Zolnerowich & Rose 2008
<i>nikolskajae</i>	Myartseva	3	Abd-Rabou 2006
<i>orientalis</i>	Gerling	5	Tzeng & Kao 1995
<i>queenslandensis</i>	Naumann & Schmidt	7	De Barro et al. 2000
<i>rajasthanicus</i>	Hayat	6	Li et al. 2011
<i>Eretmocerus</i>			
<i>ruii</i>	Zolnerowich & Rose	1, 5	Zolnerowich & Rose 2004
<i>sculpturatus</i>	Hayat	6	Li et al. 2011
<i>serius</i>	Silvestri	1, 2, 3, 5, 6, 7, 9	Abd-Rabou et al. 2005
<i>silvestrii</i>	Gerling	5	Li et al. 2011
<i>staufferi</i>	Rose & Zolnerowich	1	Rose & Zolnerowich 1997a
<i>tejanus</i>	Rose & Zolnerowich	1	Rose & Zolnerowich 1997a
<i>warrae</i>	Naumann & Schmidt	7	Kumar et al. 2008
Azotidae			
<i>Ablerus</i>			
<i>macrochaeta</i>	Silvestri	5, 6	Li et al. 2011
Encyrtidae			
<i>Metaphycus</i>	spp. (Columbia, Venezuela, USA)	1, 2	Bellotti et al. 2005, Evans 1993, present study
Signiphoridae			
<i>Signiphora</i>			
<i>aleyrodis</i>	Ashmead	1, 2, 3	Stansly et al. 1997
Platygastridae			
<i>Amitus</i>			
<i>bennetti</i>	Viggiani & Evans	1, 2	Viggiani & Evans 1992
<i>fuscipennis</i>	MacGown & Nebeker	1, 2, 3	Gerling et al. 2001
<i>hesperidum</i>	Silvestri	1, 2, 5	Li et al. 2011
<i>longicornis</i>	(Förster)	3	Li et al. 2011

new species are discovered and the host ranges of named species are expanded to include members of this cryptic species complex.

## Distribution of *Bemisia tabaci* Parasitoids

Parasitoid distribution records are numbered by geographic region following Evans (2007) and are reproduced below for ease of reference. The reader is referred to the same publication, freely available online, for in-depth information pertaining to the species listed including species synonyms, collection localities, host records, and citations. Additional information can be retrieved from John Noyes' Universal Chalcidoidea Database (<http://www.nhm.ac.uk/chalcidoids>) (Noyes 2014).

1. Nearctic – United States, Canada, and Greenland
2. Neotropical – Mexico, Central and South America, Caribbean Islands
3. Western Palearctic – Europe, North Africa (bordering the Mediterranean), Russia, the Middle East, Uzbekistan, Kyrgyzstan, Tajikistan, Afghanistan, Turkmenistan, and Azores, Madeira, and Canary Islands
4. Ethiopian – Africa south of the Mediterranean countries, Madagascar, Seychelles, and Cape Verde Islands
5. Eastern Palearctic – China, Japan, Korea, Taiwan, and Southern Primor'ye
6. Oriental – India, Pakistan, Philippines, and Southeast Asia
7. Australasian – Australia, Indonesia, and New Guinea
8. Pacific Islands – New Zealand and South Pacific Islands
9. Hawaii

WW. Worldwide

## Parasitoids of the *Bemisia tabaci* Species Complex

### *Ablerus* Howard (Chalcidoidea: Azotidae)

Species of *Ablerus* (= *Azotus* Howard) are most commonly recorded as primary, or hyperparasitoids, of immature Sternorrhyncha (Hemiptera) although certain species are known to attack lepidopteran eggs (Darling & Johnson 1984) and the pupae of chamaemyiid Diptera (Blanchard 1936). Material bred from whiteflies is typically assumed to be hyperparasitic on aphelinid primary parasitoids developing in the same host (Viggiani 1982; Evans 2007). Recently, *Ablerus macrochaeta* Silvestri was reported from *B. tabaci* in Guangxi and Yunnan Provinces in the People's Republic of China following a 10 yr natural enemy census (Li et al. 2011). Additional whitefly host records for *A. macrochaeta* include *Aleurocanthus incertus* Silvestri, and the citrus blackfly, *Aleurocanthus woglumi* Ashby. The only other instance of an *Ablerus* species attacking a whitefly in the genus *Bemisia* is *Ablerus inquirenda* Silvestri parasitizing *Bemisia* (as *Lipaleyrodes*) *euphorbiae* (David and Subramaniam) (Evans 2007).

### *Cales* Howard (Chalcidoidea: Aphelinidae)

*Cales* is a relatively poorly known genus whose members, where host relationships are known, are primary parasitoids of aleyrodine whiteflies. *Cales* are morphologically conserved and character poor making their identification difficult without the use of molecular tools

(Mottern 2012). Abd-Rabou (1997, 2002) reported a *Cales* sp. from *B. tabaci* in Beni-Suef, Egypt, citing rare incidence. At least one species, *Cales noacki* Howard, is globally distributed having been implemented in successful biological control programs for control of woolly whitefly, *Aleurothrixus floccosus* (Maskell), a severe pest of *Citrus* in many countries (Meyerdirk et al. 1980; Miklasiewicz & Walker 1990; Rose & DeBach 1994). This same species was reared from the *B. tabaci* complex in Tanzania on cassava (*Manihot esculenta* Crantz) (Guastella et al. 2014). It is important to note, however, that recent morpho-molecular analyses have identified *C. noacki* as a cryptic complex composed of at least 9 other species, some of which are indistinguishable morphologically (Mottern & Heraty 2014).

Mottern (2012) recently revised the Neotropical fauna adding an additional 21 new species. Further information is available from Mottern et al. (2011), Mottern (2012), and Mottern & Heraty (2014). The latter includes a key to male and female species and species complexes.

### *Encarsia* Förster (Chalcidoidea: Aphelinidae)

*Encarsia* is the most speciose genus of Aphelinidae with more than 450 described species which mainly parasitize either whiteflies (Aleyrodidae) or armored scale insects (Diaspididae). The number of species recorded from the *B. tabaci* species complex has greatly increased over recent years from the 35 listed in Gerling et al. (2001), to 55 in Arnó et al. (2010) to 81 here. Minus a few exceptional cases, female *Encarsia* are primary endoparasitoids whereas males develop as ectophagous hyperparasitoids on conspecific or heterospecific individuals including those of other genera (Walter 1983; Hunter & Woolley 2001). The host-associations of females appear to be obligate inasmuch as they are restricted to a particular host family (e.g., Aleyrodidae; Diaspididae; Hormaphididae) (Polaszek et al. 2009). Conversely, although male *Encarsia* are usually reared from the same host(s) as the females, they have also been obtained from alternative hosts, including soft scales (Coccidae) (Myartseva & Evans 2007), psyllid nymphs (Liviidae; Triozidae) (Polaszek et al. 1992; Butler & Trumble 2011), and the eggs of Lepidoptera (Polaszek 1991) and Cicadellidae (Hemiptera: Auchenorrhyncha) (Polaszek & Luft Albarracin 2011). The reports of the armored scale parasitoids *Encarsia aspidioticola* (Mercet) and *Encarsia lounsburyi* (Berlese & Paoli) from *B. tabaci* should be treated with caution (Greathead & Bennett 1981; Li et al. 2011), especially in regard to *En. lounsburyi*, where males are unknown.

Identification aids to *Encarsia* species are available for the following localities: Australia (Schmidt & Polaszek 2007), China (Huang & Polaszek 1998), Egypt (Polaszek et al. 1999), Hispaniola (Evans & Serra 2002), Italy (Viggiani 1987), India (Hayat 2011), Mexico (Myartseva & Evans 2007), North America (Schauff et al. 1996), and Taiwan (Shih et al. 2008). Polaszek et al. (1992) and Evans & Polaszek (1997) treated the species parasitizing the *B. tabaci* species complex. Heraty et al. (2008) recently discussed the systematics and biology of *Encarsia* with an emphasis on those attacking *Bemisia* species.

### *Eretmocerus* Haldeman (Chalcidoidea: Aphelinidae)

The genus *Eretmocerus* contains 78 nominal species all of which are solitary, obligate, primary ecto-endoparasitoids of the whitefly subfamily Aleyrodinae. Myriad undescribed species exist including several that have been reared from *Bemisia* (Zolnerowich & Rose 2008). Twenty-three of the 78 described species have reportedly been reared from the *B. tabaci* species complex. In our list, we exclude 3 species that continue to be, or have been, commonly recorded as parasitizing *B. tabaci*, namely *Eretmocerus californicus* Howard, *Eretmocerus corni* Haldeman, and *Eretmocerus haldemani* Howard. We follow the convention of Zol-



nerowich & Rose (2008) that these taxa, or their host whitefly, are being misidentified (Rose et al. 1996; Rose & Zolnerowich 1997a).

Recent efforts have been made to utilize *Eretmocerus* in biological control programs against *B. tabaci* MEAM1 at the international level. Five exotic species were released in the United States for control of MEAM1 in Florida, Texas, Arizona, and California (Nguyen & Bennett 1995; Gould et al. 2008). Following the success of one of these species, *Eretmocerus hayati* Zolnerowich & Rose, importation for evaluation and/or releases have been made in Australia (De Barro & Coombs 2009), Egypt (Abd-Rabou 2004), the People's Republic of China (Yang & Wan 2011), and Tanzania (Guastella et al. 2014). *Eretmocerus hayati* appears to display a precise level of host specificity limited to the genus *Bemisia* (De Barro & Coombs 2009), a trait possibly shared by other *Eretmocerus* from the Old World that have been reported only from this genus (e.g., *Er. emiratus* Zolnerowich & Rose, *Er. sp. nr. emiratus* [Ethiopia and Sudan], *Er. melanoscutus* Zolnerowich & Rose) (Zolnerowich & Rose 1998). Castillo & Stansly (2011) created a *nomen nudum* for *Er. sp. nr. emiratus* (Sudan) when they published its bionomics under the name *Eretmocerus sudanensis* Zolnerowich & Rose. This species is excluded from the list because it currently is not a valid species, despite being the dominant *Eretmocerus* parasitoid of *B. tabaci* in Florida (Z. Lahey, unpublished data).

Accurate identification of *Eretmocerus* depends, in large part, on the examination of properly curated material (Rose & Zolnerowich 1997a). Keys to species have been produced for the following world regions: Australia (De Barro et al. 2000), China (Wu et al. 2009), Egypt (Abd-Rabou & Evans 2002), India (Hayat 1972, 1998), Iran (Abd-Rabou et al. 2005), Italy (Viggiani & Battaglia 1983), Mexico (Myartseva 2006a), and the United States (Rose & Zolnerowich 1997a,b; Zolnerowich & Rose 1998).

### *Metaphycus* Mercet (Chalcidoidea: Encyrtidae)

*Metaphycus* are primary endoparasitoids of scale insects in the Coccoidea, although a few New World species are known to parasitize whiteflies (Myartseva 2006b) and jumping plant lice (Hemiptera: Trioziidae) (Guerrieri & Noyes 2000). An as yet undescribed *Metaphycus* sp. was reared from *B. tabaci* collected in Venezuela by F.D. Bennett, providing the first record of the genus attacking an aleyrodid (Evans 1993). A recent survey of whitefly natural enemies conducted in Columbia also yielded a *Metaphycus* sp. (Bellotti et al. 2005). In the continental United States, there exists at least a single species capable of parasitizing *B. tabaci*. Recently, specimens were reared from *B. tabaci* (presumably MEAM1) as part of a survey of the parasitoid Hymenoptera associated with the *B. tabaci* species complex in southwest Florida (Z. Lahey, unpublished data). In all instances, the adults emerged through a hole chewed in the side of the whitefly and not through the dorsum, which is the typical escape route of whitefly parasitoids. This unusual emergence behavior may be explained, in part, by the subsequent rearing of the same species from a mealybug (Hemiptera: Pseudococcidae) found inhabiting the same host plant, *Pluchea baccharis* (Miller) Pruski (Asterales: Asteraceae). This bi-parental species probably utilizes *B. tabaci* facultatively and is so infrequently collected from the whitefly that it is not of economic importance.

The species of *Metaphycus* known to attack whiteflies are all from the New World with those that are described known solely from the Neotropical realm. A key to those species is available in Myartseva (2006b), but many remain undescribed (Guerrieri & Noyes 2000).

### *Signiphora* Ashmead (Chalcidoidea: Signiphoridae)

*Signiphora* is a relatively small genus that contains primary and hyperparasitoids, most of which are distributed throughout the Neo-

tropics (Woolley 1988). *Signiphora aleyrodis* Ashmead has been reared in small numbers from *B. tabaci* in numerous surveys throughout the Neotropics (Schuster et al. 1998; Viscarret et al. 2000; de Oliveira et al. 2003) and represents the only nominal signiphorid associated with the species complex. This species is an obligate hyperparasitoid of Aphelinidae and Platygasteridae (Woolley 1988). Additional reports of unidentified *Signiphora* species reared from the *B. tabaci* complex exist from Cuba (Castineiras 1995), Columbia (Bellotti et al. 2005), Martinique (Ryckewaert & Alauzet 2002), and Argentina (Viscarret et al. 2000).

A key to the species and species groups of *Signiphora* is provided in Girault (1913) and Woolley (1988), respectively.

### *Amitus* Haldeman (Platygastridae: Platygastridae)

*Amitus* is 1 of 3 genera of whitefly parasitoids in the Platygastridae, all of which are primary endoparasitoids of whiteflies. Of the 19 species that comprise the genus, 4 (*bennetti*, *fuscipennis*, *hesperidum*, and *longicornis*) are recorded as parasitoids of *B. tabaci*. *Amitus bennetti* Viggiani & Evans was introduced into Florida from Puerto Rico for control of MEAM1 in the early 1990's (Nguyen & Bennett 1995). Although recoveries were made several weeks after initial field releases, it is unknown if this species established. Surveys conducted in southwest Florida in the mid 1990s, and from 2012–2013 did not recover this species, or any other species of *Amitus*, from *B. tabaci* (Stansly et al. 1997; Z. Lahey, unpublished data). *Amitus fuscipennis* MacGown & Nebeker is a well-known parasitoid of the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), and appears capable of utilizing *B. tabaci* in the laboratory (reference in Gerling et al. 2001); to our knowledge *A. fuscipennis* has never been reared from *B. tabaci* in the field. Both *A. hesperidum* Silvestri and *A. longicornis* (Förster) parasitize citrus pests in the genus *Aleurocanthus* Quaintance. Additional *Amitus* have been reared from *B. tabaci* in Honduras (Vélez 1993) and Nicaragua (Nunes et al. 2006).

Identification of *Amitus* is difficult due to a lack of information regarding the genus. Viggiani & Mazzone (1982) provided a key to the species of Italy. MacGown & Nebeker (1978) reviewed the species of the Western Hemisphere, and Polaszek (1997) discussed the European species. Some of the New World species were addressed by Viggiani & Evans (1992).

## Doubtful Reports

One species from each of the following 3 chalcidoid genera are recorded as parasites of the *B. tabaci* species complex: *Adelencyrtus* Ashmead (Encyrtidae), *Neochrysocharis* Kurdjumov (Eulophidae), and *Pteroptrix* Westwood (Aphelinidae). *Adelencyrtus* are parasitoids of Coccoidea (mostly Diaspididae), with 1 doubtful record of *A. moderatus* (Howard) from *B. tabaci* (Greathead & Bennett 1981). To our knowledge, *A. moderatus*, as well as any other species of *Adelencyrtus*, has never reliably been reared from an aleyrodid. Most likely the whitefly collection that produced these specimens was contaminated with diaspine scales resulting in this host association.

A similar situation arises in regards to *Pteroptrix*, also parasitoids of Diaspididae. Like the genus *Encarsia*, *Pteroptrix* exhibit heteronomous life histories with females acting as primary parasitoids and males developing as hyperparasitoids on the same or different species (Hunter & Woolley 2001). If females are capable of utilizing parasitized whiteflies as hosts for males, rearings of male but not female *Pteroptrix* from aleyrodids could be possible. Both Pruthi & Samuel (1942) and Samuel (1950) included *P. bemisiae* Mani as a *B. tabaci* parasitoid in India. Hayat (1986) considered this species a *nomen nudum*, and for this reason alone it cannot be included as a valid parasitoid of the *B.*

*tabaci* complex. In addition, no other species of *Pteroptrix* appears to be associated with whiteflies, making the relationship between *P. bemisiae* and *B. tabaci* unlikely.

The eulophid genus *Neochrysocharis* was added to the list of whitefly parasitoids following reported rearings from the 3 whitefly species, *Aleyrodes prolella* L., *Bemisia tabaci* (Gennadius), and *Tertaliccia erianthi* Danzig, in central Asia (Myartseva 1993; Myartseva & Yasnosh 1994). Typical host-associations for *Neochrysocharis* species include leaf-mining Diptera and Lepidoptera, although other taxa have also been cited (Noyes 2014). Arguably the most well-known and polyphagous species is *N. formosus* (= *formosa* Westwood), which has been bred from over 100 different host species in 5 orders (Luna et al. 2011). Although we do not completely exclude the possibility of *N. formosus* as a valid parasitoid of the *B. tabaci* species complex, or of whiteflies in general, we evince caution in doing so for the following reasons; (i) no other species of *Neochrysocharis* has been associated with the Aleyrodidae; (ii) primary whitefly parasitism in the family Eulophidae appears to be restricted to the tribe Euderomphalini; (iii) *N. formosus* and certain members of the *B. tabaci* complex have a cosmopolitan distribution and can be found within the same agricultural environment on the same host plant(s). Unless *N. formosus* displays an affinity for parasitizing a species of the *B. tabaci* complex endemic to the collection locality, one would expect subsequent collecting efforts to have produced *N. formosus* specimens from *B. tabaci* on at least one other occasion somewhere else in the world.

## Conclusions

The *B. tabaci* species complex remains a serious economic problem worldwide despite the considerable attention gained over the past 30 yr. Fortunately, the number of potential biocontrol agents used for control of these pest whiteflies continues to grow as new species are discovered and the host range of known species is expanded to include members of this cryptic species complex. In this regard, the genus *Eretmocerus* leads the way as the most important group of parasitic wasps used against *B. tabaci* whiteflies with *Er. hayati* having been introduced onto 3 continents outside its native range. It is our hope that the current work will serve as an important reference for biocontrol workers in regards to general information about the genera that parasitize *B. tabaci* whiteflies, as a portal to the references that allow for their accurate identification, and as a starting point for the construction of a comprehensive key to the species that help control this serious pest complex of world agriculture.

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