SUNTEXT REVIEWS

SunText Review of Biotechnology
ISSN: 2766-5097

Open Access
Research Article
Volume 2:3

Study of the Aspects Conceptual and Taxonomic of Aphelinidae Family (Insect: Hymenoptera)

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Received date: 07 December 2021; **Accepted date:** 21 December 2021; **Published date:** 28 December 2021

Citation: Marchiori CH (2021). Study of the Aspects Conceptual and Taxonomic of Aphelinidae Family (Insect: Hymenoptera). SunText Rev Biotechnol 2(3): 132.

DOI: https://doi.org/10.51737/2766-5097.2021.032

Abstract

The aphelinids (Aphelinidae) are a family of apocritic hymenopterans that includes tiny parasitoid wasps Biology. Parasitoids of mainly Hemiptera, also Lepidoptera, Orthoptera, Diptera, Dryinidae (Hymenoptera) and others Chalcidoidea. The purpose of this article is to obtain information on the characteristics and taxonomy of the Family Aphelinidae (Insecta: Hymenoptera). In this study, quantitative and conceptual aspects were used. A selection of articles published from 1982 to 2021. The mini review was prepared in Goiania, Goias, from September to October 2021, through the Online Scientific, internet, Research Gate, Academia.edu, Frontiers, Biological Abstract, Publons, Qeios, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science, ERIC, Science Research.com, SEEK education, Periodicals CAPES, Google Academic, Bioline International, VADLO, Scopus, Web of Science, LILACS, Medline, LIS and Portal of Scientific Journals in Health Sciences. Despite its great importance, in the biological control of whiteflies, species diversity, taxonomy, morphology and biology of Aphelinidae is little known and studied in Brazil.

Keywords: Periodicals CAPES; Hemiptera; Aphidius; Hymenopteran; Pests

Introduction

The aphelinids (Aphelinidae) are a family of apocritic hymenopterans that includes tiny parasitoid wasps [1,2]. Biology. Parasitoids of mainly Hemiptera, also Lepidoptera, Orthoptera, Diptera, Dryinidae (Hymenoptera) and others Chalcidoidea (Figures 1-3).

Figure 1: *Specimen of Aphelinidae side view.*

Figure 2: *Aphelinid wasps: Head and antennas.*

Figure 3*: Aphelinidae back view.*

Characteristics

Afelinids have a small body, on the order of 1 mm in length (0.5-1.5 mm), almost never metallic in color. The boss carries antennas of 5 to 8 items, no rings, rarely 9 items. The chest shows a well-defined, deep, and straight notauli. The legs usually have a tarsus of five articles, less frequently with 4 tarsomeres. The wings have a marginal rib if the submarginal. The postmarginal vein is very small or absent, the stigmal vein is rather short [1-3] (Figures 4-5). The abdomen is sessile, with the gastro connected to the propodeo by a broad base. The cercoids are arranged at the apex of the gastro. The terebra can have several developments, sometimes clearly protruding below the abdomen. These little insects are difficult to study; they must be carefully preserved in alcohol so that they do not deteriorate. That is why many museum specimens are not suitable for study [1-3]. The larva in most cases is parasitic or parasitoid of Hemiptera, although some attack other hosts, and the details of the life cycle vary (for example, some attack eggs, other nymphs and others are hyperparasites, that is, they parasitize to other parasites). Males and females can have different hosts and different life cycles [4-6] (Figures 6-12).

Habitats and taxonomic

They are distributed worldwide in a great variety of habitats. Some species are used as biological pest control agents. They are difficult to separate from other members of the Chalcidoidea superfamily except for subtle wing venation details. In 36 genera, in seven subfamilies worldwide 1200 species, two of them, Azotinae and Eriaporinae, are now considered separate families. It is possible that it is a paraphyletic group and therefore there is a need to subdivide it in the future. For example, the Calesinae subfamily can become a separate family [4-7] (Figure 13,14).

Phenology

The aphelinids are important parasitoids in the biological control of pests worldwide. Most of the species are multivoltine, they develop continuously throughout the year. However, winter diapause occurs in the larval stage, particularly in species that develop in hosts that overwinter as eggs. The number of generations per year depends mainly on climatic factors, it also depends on the host and the geographical region [7,8] (Figures 15,16).

Biology

The biology of Aphelinids is quite complex and characterized by unique behaviors. An important aspect is the notable trophic specialization within this family and the frequency of sexual dimorphism in the parasitic relationship, often also correlated with a morphological dimorphism in the 1st age larvae stage [9] (Figure 17).

Primary ditrophic arrenoparasitism: females are primary endoparasites, male's primary ectoparasites. Both sexes attack Rincoti's pre-imaginary stages. Primary heterotrophic arrenoparasitism: females are associated with pre-imaginary stages of Rincoti, while males are oophagic parasites of Lepidoptera [9]. Secondary autotrophic arrenoparasitism: males are obligate hyperparasites at the expense of female larvae of their own species (obligatory autoparasitism) [9]. Secondary heterotrophic arrhenoparasitism: males are hyperparasitic and can develop indifferently at the expense of female larvae of their own species or of larvae of both sexes of different species (facultative autoparasitism). Force secondary heterotrophic arrhenoparasitism: males are hyperparasitic and develop exclusively at the expense of parasitoids of different species (absence of self-parasitism) [9]. A second classification is more schematic because it groups male hyperparasitism cases into subcategories of a general one (heteronomic hyperparasitism) [9].

Systematics

The internal systematics of this family are subject to continual and controversial reviews. Despite the morphological and ethological homogeneity, many authors have doubts about the exact systematic placement of different species within genera or even within the family. As an indication, the family would include more than a thousand species divided into more than 30 genera that belong to 7 subfamilies [9,10].

Objective

The Objective of this work is to investigate the characteristics and taxonomy of the Aphelinidae Family (Insecta: Hymenoptera).

Methods

The method used to prepare this mini review was Marchiori 2021 methodology [9].

Studies conducted and selected

Study 1

Aphelinus sp. (Aphelinidae family) Characteristics: Biological cycle – egg, larva, pupa, and adult. Adult – 1 to 3 mm in length; compact body, with well-joined chest and abdomen; big eyes; short antennas; four transparent wings; head and chest with black color and yellow-brown abdomen; abdomen. The female has a pointed ovipositor at the end of the abdomen, with which she pierces the body of the nymph (immature stage) of the aphid to lay its egg.
Larva – like A worm; no legs; live inside the host (endoparasitoid), it feeds on the body's fluids and tissues and causes its death when it completes the larval stage. Signs of activity - aphid attached to the leaf and mummified black, which may present an orifice circular in the upper abdomen, corresponding to the exit site of the

adult micro wasp. Importance – aphid nymph parasitoid that infests various vegetables; adults are free-living and feed on nectar and pollen.

Importance – nymph parasitoid (immature form) of various species of whiteflies; adults are free-living, feed on nectar, but also prey on small whitefly nymphs Bemisia tabaci (Hemiptera: Aleyrodidae) and Trialeurodes vaporariorum (Hemiptera - Homoptera: Aleyrodidae) [11].

Study 2

Parasitoid whitefly micro wasps *Encarsia* spp. (Aphelinidae family) Characteristics: Biological cycle – egg, larva, pupa, and adult. Adult – 0.6 mm long; bright yellow or brownish black body, or with light brown antennae, dark brown head, black chest and bright yellow abdomen; four transparent wings, covered with short hair and fringed with long hair compact body, with well-joined chest and abdomen; pointy female has a sting-shaped ovipositor at the end of the abdomen, with which it pierces the body of the nymph (immature stage) of the aphid to lay its egg [11] (Figures 18-25).

Larva – similar to a worm; no legs; it lives inside the host (endoparasitoid) and causes its death upon completion of the larval stage. Pupa – amber, brown or black coloration; sheltered by the transparent exuvia (skin) of the whitefly nymph. Signs of activity – parasitized nymphs with amber, brown or corresponding parasitoid pupa inside; whitefly empty pupae with a circular hole in the upper part, where the adult micro wasp exited [11].

Study 3

The present work is the first study of Aphelinidae in Veracruz.

Until the year 2000, only eight species of Aphelinidae were known in the state of Veracruz). At present, the fauna of this family consists of 29 species in seven genera; 10 of these species were described as new in the last decade (30.5% of the local fauna). Worldwide, the genera of Aphelinidae with the most species are also Encarsia Förster, Coccophagus Westwood and Aphytis Howard. In Veracruz, 15 species of Encarsia have been determined, five of Aphytis and four of Coccophagus. Most (17) are whitefly parasitoids (Aleyrodidae), six species attack armed scales (Diaspididae), and four species parasitize soft scales (Coccidae) while one species consumes aphids (Aphididae). Have only been found to date in Veracruz. In the authors' opinion, Aphelinidae is undoubtedly richer in species in Veracruz since it houses host insects that feed on plants from various ecosystems and agroecosystems, which is why it is necessary to continue the study [12] (Figures 26,27).

Study 4

The genus Encarsia Förster, (Hymenoptera: Aphelinidae: Coccophaginae) comprises more than 400 species described worldwide, distributed in 26 groups. Mostly parasites of whitefly nymphs (Aleyrodidae) and carapace scale scales (Diaspididae), but some species, especially those belonging to the Encarsia flavoscutellum Zehntner, 1900 group, can parasitize aphids (Hormaphidine) Generally the females are primary parasitoids of whiteflies and carapace scale insects and the male parasitoids of the same species or another species of Encarsia. Virgin females deposit the unfertilized eggs that will give rise to males, externally on the larva of the third instar female of the Encarsia species itself (Figure 28).

However, some species have different behavior as in the case of Encarsia porteri (Mercet, 1928), in which males are facultative primary parasitoids of lepidopteran eggs or parasitoids of females of their own species. In the species Encarsia inaron (Walker, 1839) and Encarsia longicornis Mercet, 1928 both males and females are primary parasitoids of whitefly nymphs (Figure 29) [13,14].

The parasitoids of the Encarsia genus are of variable coloration, some species may be completely pale yellow or with brown spots. Generally, the male is darker than the female, with a brown or dark brown coloration. The body is composed of the head, thorax or mesosome, including the propodium, first abdominal segment and the gaster or metasome. The head in front view is wider than it is long, composed of a pair of compound eyes, three ocelli placed triangularly between the compound eyes, clypeus, mandible usually with three or two teeth, maxillary palps with one, or rarely two segments (Figure 30) [15,16].

The important morphological characteristics for the identification of Encarsia spp., in addition to the body color, are the measurements of the funiculus segments, presence, location and number of longitudinal sensilla in the antenna; arrangement of arrows and veins in the anterior wing; number of arrows in the middle lobe of the midlobe; distance between the scutellar sensilla and the length of the arrow located in the scutellum; relationship between the length of the ovipositor and the median tibia, measured from the second valve and third valve and arrows from the tergites in the gaster (Figure 31) [17,18].

In most Encarsia species both males and females develop on different hosts. Females are primary endoparasitoids and develop in whitefly nymphs or carapace scale insects and males can develop as hyperparasitoids in females of the same or another species or in lepidopteran eggs. Some Encarsia species are associated with Wolbachia and other specialized groups of symbiotic bacteria, which cause disturbances in the sex ratio of the progenies. These females infected with these symbionts start to reproduce by telitoca parthenogenesis, producing only females and males are generally absent (Figure 32) [17,18].

Females of Encarsia spp. preferentially parasitize third instar nymphs and lay one or more eggs inside the host body; however, only one larva will complete its development. The egg of Encarsia spp. it is oval measuring approximately 30μm in width by 70μm in

length encased in a smooth, translucent membrane. The larva has a vermiform appearance, covered with a hyaline membrane, non-segmented and measures approximately 150µm in width and 450µm in length [19] (Figures 33-36).

Study 5

Aphelinus is a genus of parasitoid wasps. Several of the species are important because they parasitize agricultural pests, such as the soybean aphid (Aphelinus certus Yasnosh, 1963) or the Russian wheat aphid -Diuraphis noxia (Kurdjumov, 1913) - Aphelinus ibipodus Hayat & Fatima, 1972, Aphelinus asychis Walker, 1839 and Aphelinus varipes (Foerster, 1841). About 100 species have been described. Biological control of aphids Aphelinus abdominalis Dalman, 1820 [20,21] (Figure 37).

Figure 4: *Coccophagus japonicus Chen, Ye, Li, Cheng-De (2017): Compere, 1924, ♀: 21, head, frontal view; 22, antenna; 23, mesoscutum; 24, posterior half of mesosoma; 25, fore wing; 26, legs; 27, metasoma..*

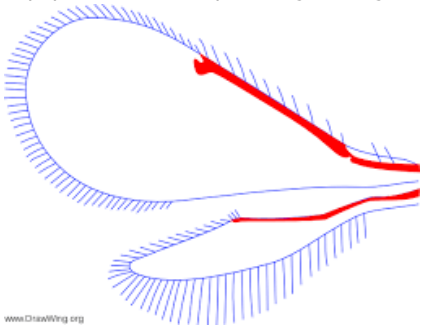
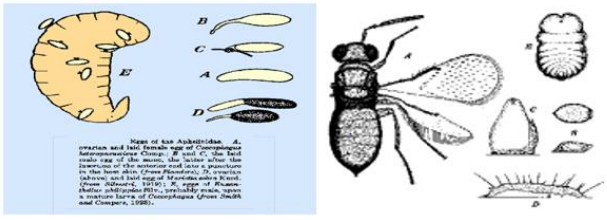
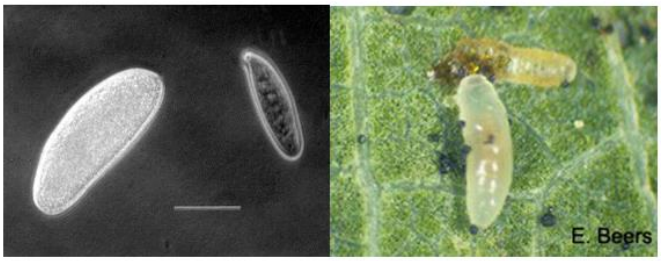


Figure 5*: Wings of Aphelinidae.*



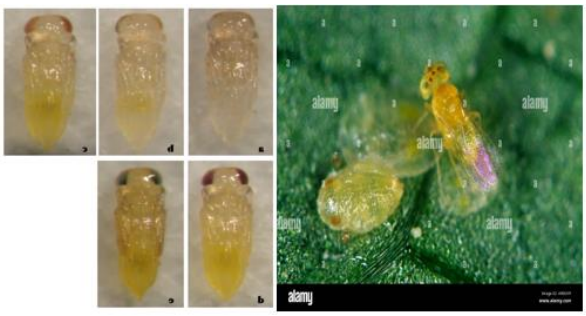
A B

Figure 6: *The eggs of Ablerus, Bark, Encarsia, Eretmocerus, and Physcus, and those of Coccophagus of primary habit, are of simple form, ranging from lemon-shaped to kidney-shaped and cylindrical. That of Eretmocerus serius Silvestri, 1927 is distinctly flattened, owing presumably to its being compressed between the host body and the leaf after deposition. Figure 6B Smith and Compere recorded an unusual modification in the egg of Euxanthellus philippiae (Silvestri, 1915). The ovarian egg is simple; yet after its deposition it is found to be attached to the host larva by a pedicel arising at the center of the ventral side. This pedicel apparently is formed in the same manner as that of the male eggs of Coccophagus lycimnia (Walker, 1839) and Coccophagus heteropneusticus (Brèthes, 1918), which are discussed in the following section, and it may, in fact, be a male egg, also.*



A B

Figures 7: *Aphilinid wasps Eggs: Laid in host aphid. Not observed. Larvae: Elongate and without features Not observed. Parasitized woolly apple aphids are hardened, black and somewhat swollen.*



A B

Figures 8: *Pupae: Found within parasitized aphids. Features such as legs and antennae becoming apparent, black. Adults: Small (0.6-4 mm). Yellow, brown, or black wasps that lack a metallic appearance. Wasp is slightly smaller than the aphid host in which it lays its eggs. Circular exit holes are cut as it chews its way out of the dead aphid.*

Figure 9: *Adult Encarsia perplexa Huang & Polaszek, 1998; and (B) pupal cases of the citrus blackfly, Aleurocanthus woglumi Ashby, 1915*

from which parasitoids have emerged (see roundish black holes). Normal emergence of an adult blackfly would leave a T-shaped split in the pupal case.

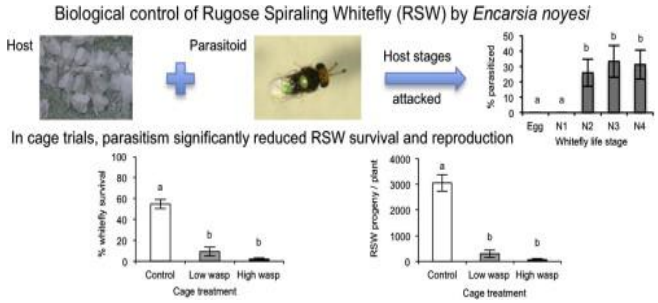


Figure 10: *Rugose spiraling whitefly (RSW), Aleurodicus rugioperculatus Martin, 2004 is an invasive species that was first detected in the United States as a pest in urban landscapes in Miami Dade County in south Florida in 2009. Subsequently RSW has spread to become a serious nuisance pest on ornamental plants and palms in urban areas across south Florida.*

Figure 11: *Hymenoptera-Aphelinidae-Marietta-Chalcid Wasps FEMALE (A).*

Figure 12: *Hymenoptera-Aphelinidae-Marietta-Chalcid Wasps MALE (D). Marietta leopardina Motschulsky, 1863 (Hymenoptera: Aphelinidae) and is obligate Hyperparasitoids of Tamarixia radiata (Waterston, 1922) (Eulophidae) and Diaphorencyrtus aligarhensis (Shafee, Alam & Agarwal, 1975) (Hymenoptera: Encyrtidae).*

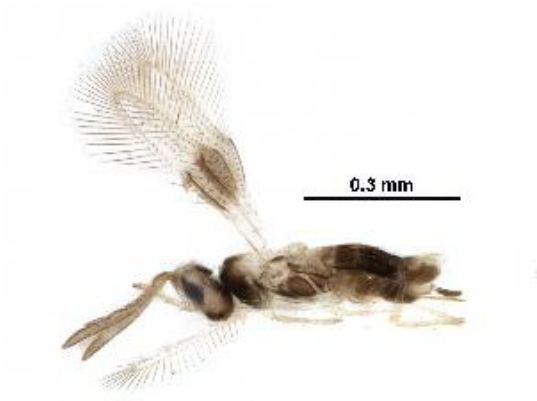


Figure 13: *The larvae of the majority are primary parasitoids on Hemiptera, though other hosts are attacked, and details of the life history can be variable (e.g., some attack eggs, some attack pupae, and others are hyperparasites). Males and females may have different hosts and different life histories. They are found throughout the world in virtually all habitats, and are extremely important as biological control agents.*

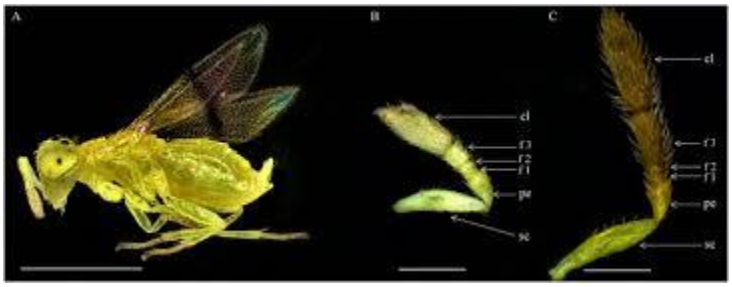


Figure 14: *The aphid parasitoid, Aphelinus maculatus Yasnosh, 1979 (Hymenoptera: Aphelinidae), first described as a new record in China in 2016, is one of the most important natural enemies of the Chinese wolfberry aphids. In order to relate its larval development stages to morphological changes of both the parasitoid and its host aphid during the parasitoid development, and to explore the larval taxonomic significance.*

Figure 15: *In general, Aphelinids are ectophagous or endophageal parasitoids at the expense of preimaginal stages of Rincoti Homoptera (especially scale insects) or hyperparasites at the expense of other parasitoid Rincoti Calcidoids (mainly Encirtids, Eulophids, Aphelins).*

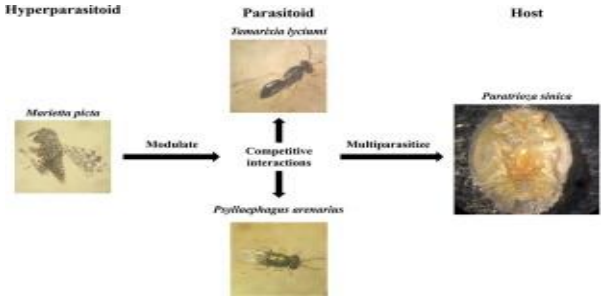


Figure 16: *The ectoparasitoid Tamarixia lyciumi Yang sp. nov. (Hymenoptera: Eulophidae) and the endoparasitoid Psyllaephagus arenarius Trjapitzin, 1967 (Hymenoptera: Encyrtidae) are solitary nymphal parasitoids of Paratrioza sinica Li &Yang, 1982 (Hemiptera: Psyllidae), a pest of goji berry, Lycium barbarumm L., 1753 (Solanaceae). Moreover, T. lyciumi is frequently attacked by a hyperparasitoid Marietta picta Andre, 1878 (Hymenoptera: Aphelinidae) in the field.*

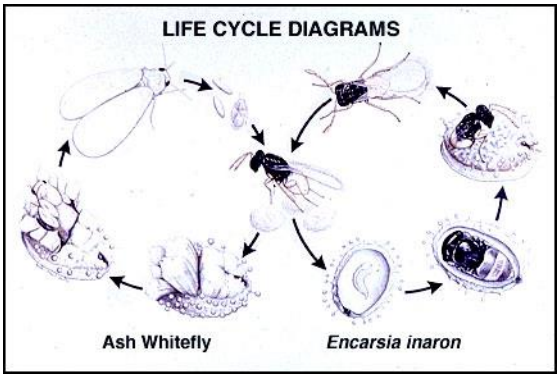


Figure 17: *Parasitoids oviposit into third and fourth instar whiteflies and complete their development inside the whitefly host. The developing larvae become banana shaped and translucent in color, inside late instar whitefly nymphs, but can only be seen through dissection and with the aid of a microscope. Parasitoids at 25C take approximately three weeks to develop from eggs to adults. At the same temperature, adults live two to three weeks, laying about 159 eggs each.*

Figure 18: *Aphelinus kazakhstanensis sp. Nov., paratype in 95% ethanol 5a male, antennae and face, anterior view, 5b female, antennae and face, anterior view 5c male, habitus, lateral view 5d female, habitus, lateral view 5e male, habitus, ventral view; 5f: female, habitus, ventral view.*

Figure 19: *Insect, Aphelinidae, Aphelinus abdominalis Dalman, 1820, Hymenopterans, Aphidius.*

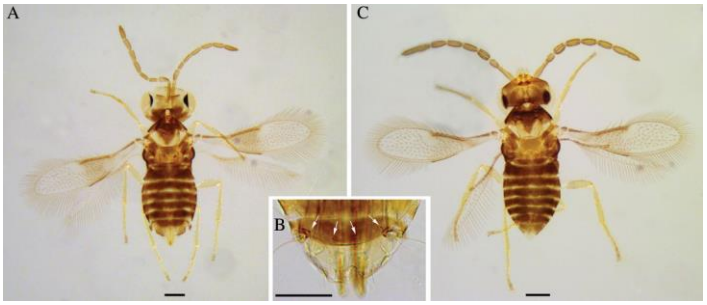


Figure 20: *Encarsia marthae Pedata & Giorgini, 2016: (A) female; (B) setae on sixth tergite (indicated by arrows); (C) male. Scale bar=100µm.*

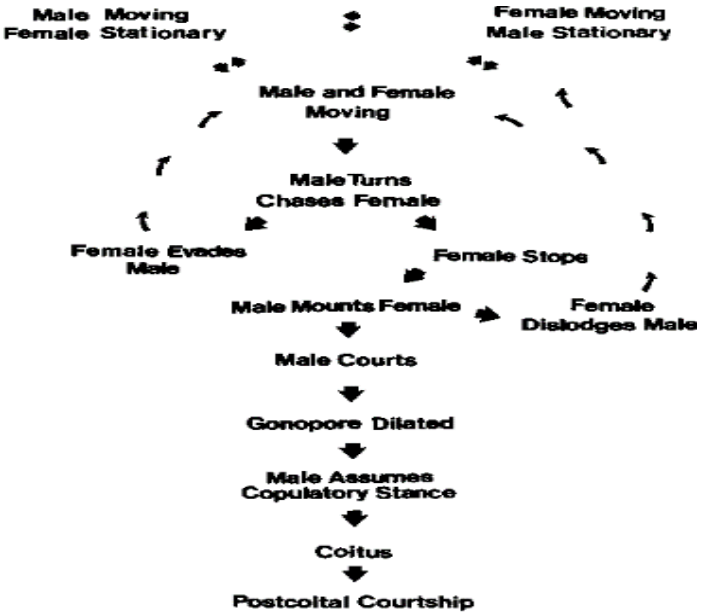


Figure 21*: Schematic diagram of hierarchical features of courtship behavior in the lingnanensis group.*

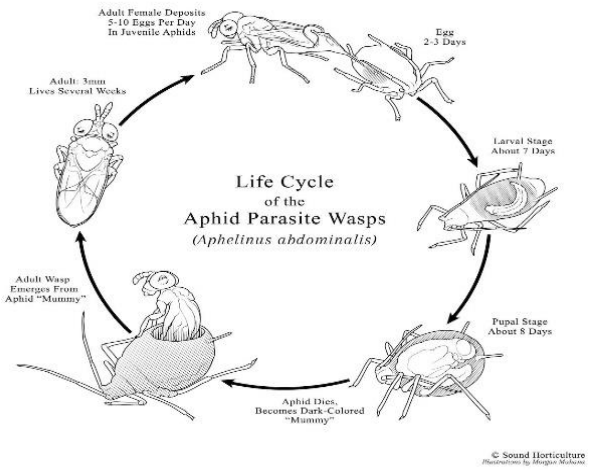


Figure 22: *Biological cycle.*

Figures 23: *Parasitic wasp, Aphelinus sp., as an effective antagonist of aphids.*

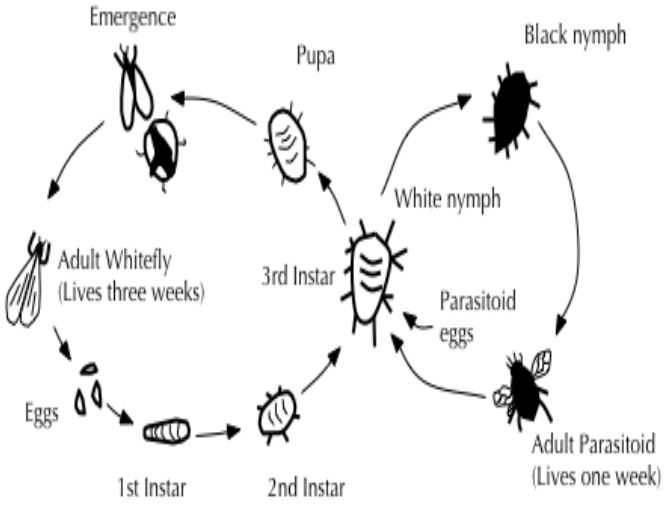


Figure 24: *Life cycles of greenhouse whitefly and its parasitoid wasp Encarsia spp.*

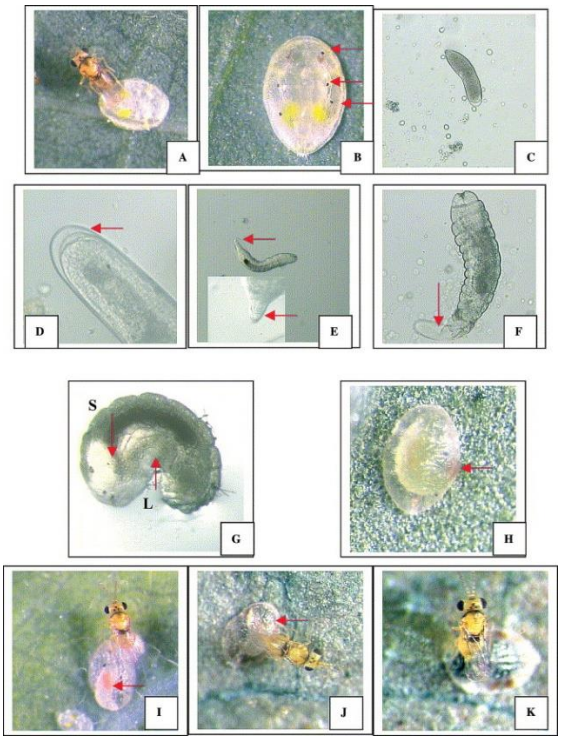


Figure 25: *Development of Encarsia bimaculata (Heraty & Polaszek, 2000) (Hymenoptera: Aphelinidae) in Bemisia tabaci Heraty & Polaszek, 2000 (Hemiptera - Homoptera: Aleyrodidae) (Gennadius) nymphs.*

Figures 26*: Aphytis is a genus of wasps belonging to the superfamily Chalcidoidea of the family Aphelinidae. Members of this genus are very small, measuring between two to three millimeters in length and are mostly black or yellow in color and have transparent wings. Larvae are parasites of other insects.*

Figures 27*: Adults are black and females differ from males because they have a yellow spot on the thorax. In the spot they only have three pairs of*

hairs that differentiate them from the female Coccophagus that have many. Coccoids parasitized by Coccophagus can be differentiated in the field from those parasitized by Metaphycus spp. because they take on a dark hue. Coccuphagus is a facultative hyperparasitoid; the females develop by feeding on the coccids while the males do so on larvae and pupae of parasitoids of the genus Metaphycus.

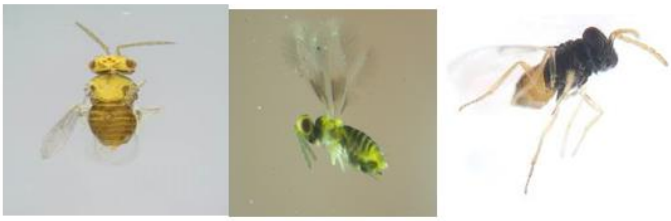


Figure 28: *Specimens of Encarsia berlesei.*

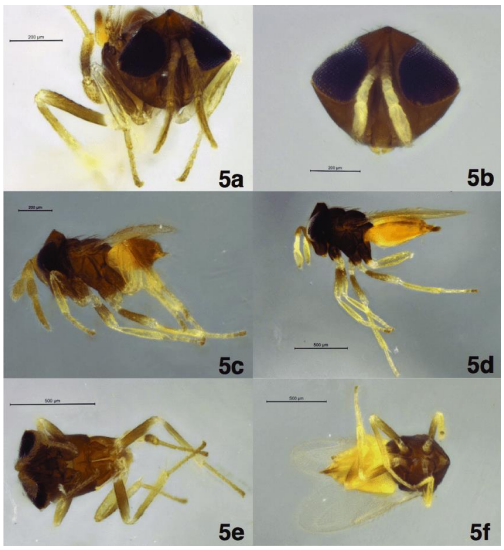


Figure 29: *Aphelinus kazakhstanensis sp. nov., paratypes in 95% ethanol 5a male, antennae and face, anterior view, 5b female, antennae and face, anterior view, 5c male, habitus, lateral view, 5d female, habitus, lateral view, 5e male, habitus, ventral view, 5f: female, habitus, ventral view.*

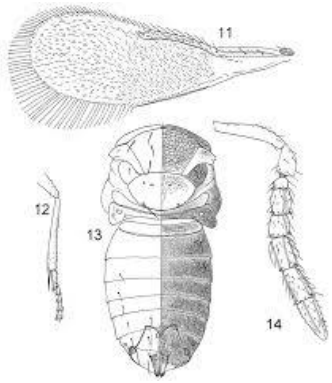


Figure 30: *Encarsia sp., 11. fore wing; 12. mid leg; 13. mesosoma and gaster; 14. antenna (female).*

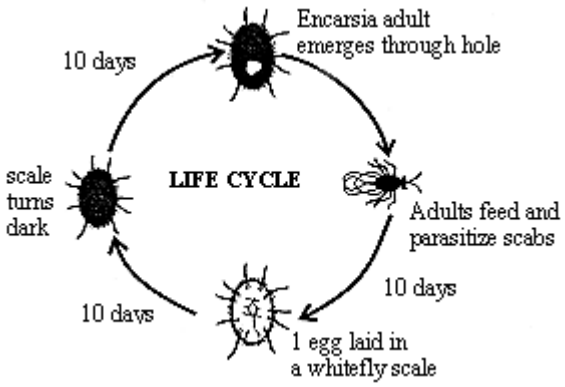


Figure 31: *Life Cycle Encarsia.*

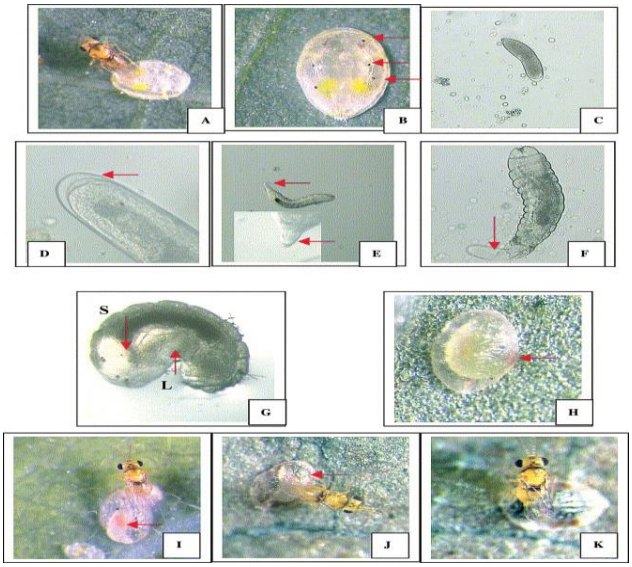


Figure 32: *Both sexes have an egg, three larval instars, prepupal, and pupal stages. Development from egg to adult took 12.70 ± 2.10 days for females and 14.48 ± 2.60 days for males.*

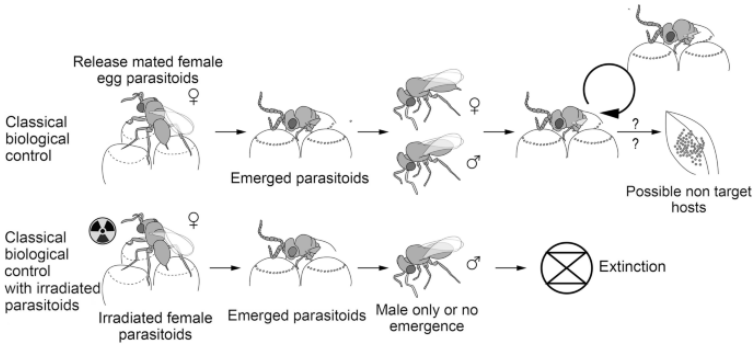


Figure 33: *While CBC (classical biological control) is potentially less costly than other approaches, complete eradication is difficult, especially when pests can sustain their populations at low levels. The sterile insect technique (SIT) involves the mass rearing and release of sterilized insects to disrupt fecundity. This has proven to be synergistic with the release of*

biological control agents such as egg parasitoids. Here we describe a newly conceptualized tool, the 'Kamikaze Wasp Technique' (KWT)

Figure 34: *Whitefly is a major pest in the greenhouse and veg patch and can devastate plants. Control it by introducing encarsia on small white cards hung on the infected plants. The encarsia (Control Encarsia) quickly hatch from the dots and munch away the whitefly.*

Figure 35: *In northwestern Indian Himalayan region, the immature stages of greenhouse whitefly, (Westwood, 1826) (Hemiptera - Homoptera: Aleyrodidae) were found parasitized by an aphelinid parasitoid. The examination of female adults revealed the identity of the parasitoid as Encarsia formosa Gahan, 1924. Under protected cultivation, the extent of Parasitization by E. formosa was up to 78%.*

Figure 36: *Natural Enemies: Enermix Cards 3,000 hatching Parasitic Wasps - Eretmocerus eremicus Rose and Zolnerowich, 1997 and Encarsia formosa Gahan, 1924.*

Figures 37: *Insect, Aphelinidae, Aphelinus abdominalis, Hymenopterans, Aphidius, Aphid, Aphelinus abdominalis.*

Partial species list

Aphelinus abdominalis Dalman, Aphelinus albipodus Hayat & Fatima, Aphelinus asychis Walker, Aphelinus certus Yasnosh, Aphelinus chaonia Walker, Aphelinus flaviventris Kurdjumov, Aphelinus humilis Mercet, Aphelinus lapisligni Howard, Aphelinus mali (Haldeman), Aphelinus semiflavus Howard, Aphelinus thomsoni, Graham, Aphelinus varipes (Foerster) [20,21].

Datasheet Type(s)

Natural Enemy; Preferred Scientific Name Aphelinus; Preferred Common Name aphelinid.

Taxonomic Tree

Domain: Eukaryota; Kingdom: Metazoa; Phylum: Arthropoda; Subphylum: Uniramia; Class: Insecta; Natural enemy of Aphis craccivora Koch, 1854 (Hemiptera: Aphididae), Brevicoryne brassica Linnaeus, 1758) (Homoptera: Aphididae), Diuraphis noxia (Kurdjumov, 1913 (Hemiptera: Aphididae), Macrosiphum rosae (L., 1758) (Homoptera, Aphididae) and Rhopalosiphum rufiabdominalis (Sasaki, 1899) (Homoptera: Aphididae) [20,21].

Conclusion

The Aphelinidae family has great economic importance in the biological control of insects. Studies of native fauna of the species are of great interest for natural and applied biological control within the philosophy of integrated pest management. Despite its great importance, in the biological control of whiteflies, species diversity, taxonomy, morphology and biology of Aphelinidae is little known and studied in Brazil.

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