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(REVIEW ARTICLE)

Family Eulophidae of economic importance for agriculture (Insecta: Hymenoptera)

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Abstract

The biology of this family is extremely diversified, being known as ectoparasitoids or endoparasitoids of a wide range of hosts, from spiders, insect eggs, nematoids, mites, thrips and even other Hymenoptera, encompassing moreof 100 families in 10 orders of arthropods. They are important as biological control of certain pests. The aim is to describe the Family of the Eulophidae of economic importance in agriculture (Insecta: Hymenoptera) related to its biogeography, bioecology, habitat, geographic distribution, taxonomy, life cycle, phenology and taxonomic and conceptual aspects of the Family, Subfamilies and Species. To this end, a bibliographic survey of Eulophidae was carried out in the years 1984 to 2021. Only complete articles published in scientific journals and expanded abstracts presented at national and international scientific events, Doctoral Thesis and Master's Dissertation were considered. Data were also obtained from platforms such as: Academia.edu, Frontiers, Qeios, Pubmed, Biological Abstract, Publons, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science and ERIC.

Keywords: Agricultural; Scielo; Caterpillar; *Diatraea saccharalis*; Brazil

1. Introduction

The Eulophidae are distinguished from other chalcidids because the legs have only 4 segments or tarsomeres and a small protibial spur instead of a long, curved one like other chalcidids. The antennae have 2 to 4 intermediate segments, between the base and the enlarged end, called funiculus (Figures 1, 2, 3, 4, 5, 6 and 7) [1,2].

Figure 1 Specimen of Eulophidae; (Source: https://alchetron.com/Eulophidae)

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Figure 2 Male and female of Eulophidae; (Source: https://zenodo.org/record/258725#.Ye1f4-rMLIU)

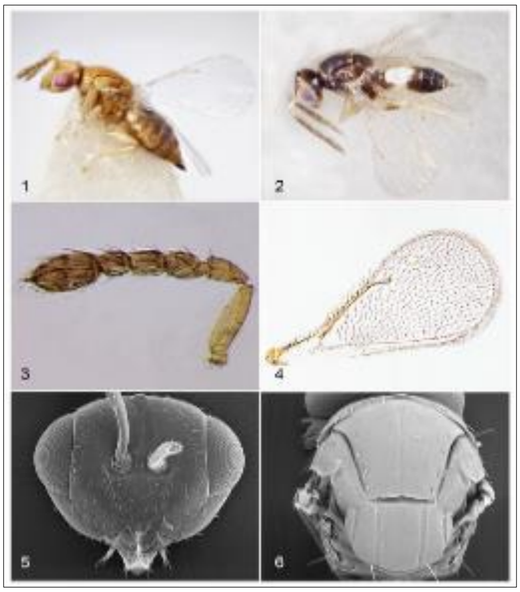


Figure 3 1. Holotype female, habitus. 2. Male habitus. 3. Female antenna. 4. Female forewing. 5. Female head. 6. Female mesosome; (Source: https://www.researchgate.net/figure/FIGURES-1-6-Aprostocetus-causalis-1-Holotype-female-habitus-2-Male-habitus-3_fig1_264419301)

Figure 4 13. Female (Florida). 14 Female (Guadeloupe). 15. Female (Puerto Rico). 16. Male (British West Indies); (Source: https://www.researchgate.net/figure/FIGURES-13-16-Aprostocetus-gala-13-Female-Florida-14-Female-Guadeloupe-15_fig3_264419301)

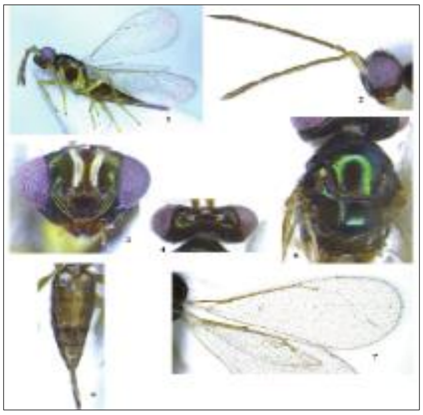


Figure 5 (Female) 1. Profile, 2. Antenna, 3. Head anterior view, 4. Head dorsal view, 5. Mesosoma, 6. Gaster, 7. Wing; (Source: https://www.researchgate.net/figure/FIGURES-13-16-Aprostocetus-gala-13-Female-Florida-14-Female-Guadeloupe-15_fig3_264419301)

Figure 6 (Female) 8. Profile, 9. Antenna, 10. Head anterior view, 11. Head dorsal, 12. Mesosoma, 13. Gaster, 14. Wing, 15. Propodeum; (Source: https://www.researchgate.net/figure/15-Aprostocetus-petiolatus-Narendran-Minu-sp-nov-Female-8-Profile-9-Antenna_fig2_275966300)

Figure 7 428 habitus in lateral view, female 429 head in frontal view, female 430 head in frontal view, male 431 gaster in dorsal view, female 432 gaster in dorsal view, male 433 antenna in lateral view, female 434 antenna in lateral view, male; (Source: https://zookeys.pensoft.net/article/4835/)

Many of the museum specimens are useless for study. The larvae of a few species feed on plants but most are parasitoids of a wide variety of arthropods, especially Lepidoptera, Coleoptera, Diptera, Hymenoptera and Homoptera. They attack them at different stages of their development, there are even some that specialize only in eggs and some groups we can attack pré-pupae and pupae. In addition to the groups mentioned, some are parasites of Thysanoptera, which is rare among parasitic Hymenoptera (Figure 8) [3,4].

Figure 8 Female *Tetrastichus howardi* (Olliff, 1893) (Hymenoptera: Eulophidae) parasitizing fourth-instar caterpillar of *Anticarsia gemmatalis* Hübner, 1818 (Lepidoptera: Noctuidae); C–Fifth-instar caterpillar parasitized by *T. howardia* after 96 hours; D–Characteristic aspect of the process of parasitism by females of *T. howardi*, acquiring dark coloration and integument hardening; (Source: https://docplayer.com.br/129254996-Desempenho-biologico-de-tetrastichus-howardi-hymenoptera-eulophidae-em-lagartas-pupas-e-erebidae-em-condicoes-de-laboratorio-e-semi-campo.html)

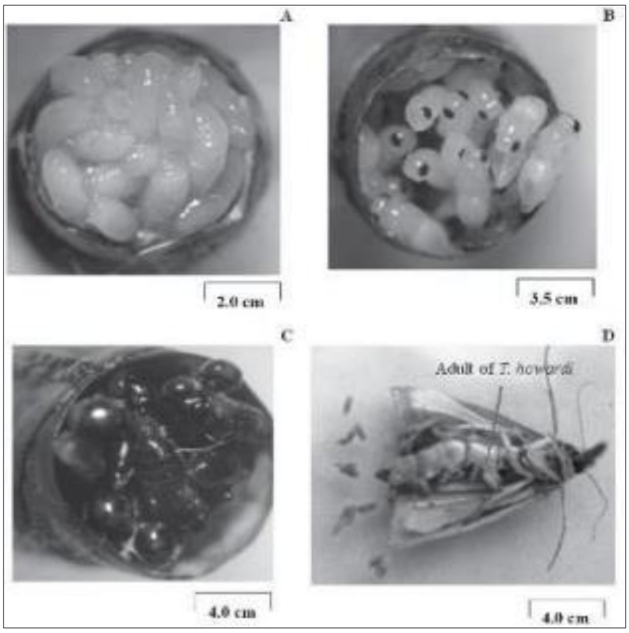


Figure 9 Larvae, pupae and adults of *Tetrastichus howardi* (Olliff, 1893) (Hymenoptera: Eulophidae) in pupae of *Diatraea saccharalis* (Fabr., 1794) (Lepidoptera: Crambidae) (A, B, C); *D. saccharalis* adult parasitized by *T. howardi* (D); (Source: Pereira FF, Kassab SO, Calado VRF, Vargas EL, Oliveira HN, Zanuncio JC. Parasitism and Emergence of *T. howardi* on *D. saccharalis*)

The biology of this family is extremely diversified, being known as ectoparasitoids or endoparasitoids of a wide range of hosts, from spiders, insect eggs, nematoids, mites, thrips and even other Hymenoptera, encompassing moreof 100 families in 10 orders of arthropods. They are important as biological control of certain pests (Figures 9, 10, 11 and 12) [5,6].

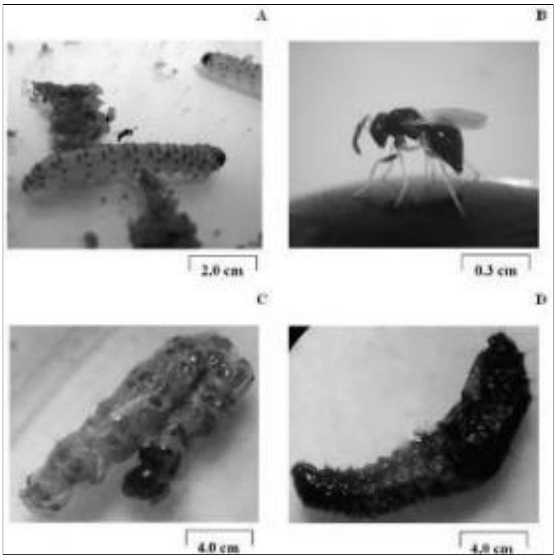


Figure 10 Female parasitizing fifth instar caterpillar and pupa of *Diatraea saccharalis* (Fabr., 1794) (Lepidoptera: Crambidae) (A and B) and hosts after parasitism (C and D); (Source: Pereira FF, Kassab SO, Calado VRF, Vargas EL, Oliveira HN, Zanuncio JC. Parasitism and Emergence of *Tetrastichus howardi* (Hymenoptera: Eulophidae) on *Diatraea saccharalis* (Lepidoptera: Crambidae) larvae, pupae and adults. Florida Entomologist. 2015: 98(1), 377-380)

Figure 11 Egg (A); first-instar larva (B, C); second-instar larva (D); third-instar larva (E); pre-pupa (F); pupa at three different stages of melanization (G, H, I). Scale bar = 0.1 mm; (Source: https://www.sciencedirect.com/science/article/pii/S0085562619300433)

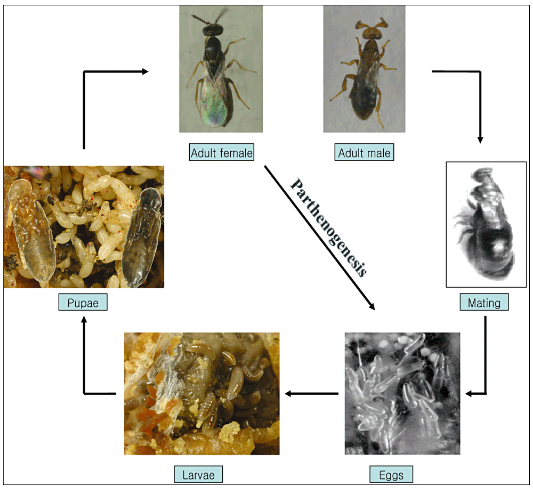


Figure 12 Mated females laid fertilized eggs that produced adult males or females, whereas virgin females laid unfertilized eggs that produced males. Development durations of the virgin female originated eggs, larvae, pupae and adults were statistically identical with those of mated females; (Source: https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1748-5967.2011.00360.x)

Eulophyids are found all over the world and in all kinds of habitats (there is even an aquatic one that parasitizes beetles of the Psephenidae family) [7, 8]. In the fight against leaf miners, eulophids are the control agents most important biological ones. In the Neotropics, for example, *Liriomyza* species (Diptera: Agromyzidae), true polyphagous pests, are parasitized by *Chrysocharis flacilla* Walker 1842, *Chrysocharis ignota* Hansson, 1987, *Chrysocharis tristis* Hansson, 1987, *Chrysocharis venones* Walker, 1842, *Closterocerus pulcher* (Girault, 1923), *Neochrysocharis diastatae* Howard, 1881, *Proacrias thysanoides* De Santis, 1972, *Proacrias xenodice* Walker, 1842, *Diaulinopsis callichroma* Crawford, 1912, *Diglyphus begini* Ashmead, 1904, *Diglyphus intermedius* Girault, 1916, *Diglyphus websteri* Crawford, 1912, *Zagrammosoma lineaticeps* Girault, 1915 and for many others (Figure 13) [9,10].

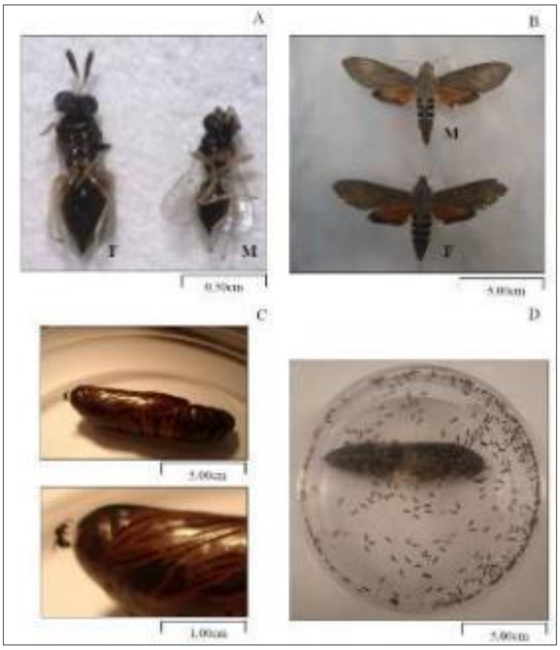


Figure 13 Adults of *Tetrastichus howardi* (Olliff, 1893) (Hymenoptera: Eulophidae) [female (F) and male (M)] (A); Adults of *Erinnyis ello* L. 1758 (Lepidoptera: Sphingidae) [female (F) and male (M)] (B); Pupae of *E. ello* being parasitized by *T. howardi* female (C); Adults of *T. howardi* newly merged from *E. ello* pupa (D); (Source: Barbosa RH, Kassab SO, Pereira UFF, Rossoni C, Costa DP, Berndt MA. Parasitism and biological aspects of *Tetrastichus howardi* (Hymenoptera: Eulophidae) on *Erinnyis ello* (Lepidoptera: Sphingidae) pupae. Rural Science. 2015; 45(2): 185-188)

Some representatives of the Eulophini tribe parasitize lepidopteran pests. *Elachertus ceramidiae* Burks, 1962 for example, attacks *Antichloris viridis* Druce, 1884 (Arctiidae), which is a moth banana blight; *Euplectrus comstockii* Howard, 1882 and *Euplectrus plathypenae* Howard, 1882 parasitize *Spodoptera* sp. and other Noctuidae and *Euplectrus puttleri* Gordh, 1980 parasite *Anticarsia gemmatalis* Hübner, 1818 (Figure 14) [9,10,11].

Figure 14 Female *Tamarixia radiata* (Waterston, 1922) ovipositing into an early 5th instar *Diaphorina citri* Kuwayama 1908 (Hemiptera: Psylidae) nymph; (Source: Photo by J. Lotz, FDOCS-DPI and Xulin C, Stansly, PA. Biology of *Tamarixia radiata* (Hymenoptera: Eulophidae), parasitoid of the *Citrus* greening disease vector *Diaphorina citri* (Hemiptera: Psylloidea): A mini review. Florida Entomologist. 2022; 97(4): 1404-1413)

Eulophidae are also used to combat Thysanoptera, in which *Ceranisus menes* Walker, 1889 (Entedoninae) effectively parasitizes the species *Thrips palmi* Karny, 1925 (Thysanoptera: Thripidae) which is a pest of several vegetable crops. And finally*, Aprostocetus hagenowii* Ratzeburg, 1852 (Tetrastichinae) is well known by parasitizing the eggs of the cockroach *Periplaneta americana* Linnaeus, 1852 (Blattidae) (Figure 15) [9,10,11].

Figure 15 *Aprostocetus exertus* Salle, Ramadan & Kumashiro, 2009 La Salle. Fig. 1. ♀ Habitus. Figs 2–3. Female wasp searching for galls. Fig. 4. *A. exertus* egg on EGW pupa. Fig. 5. *A. exertus* larva feeding externally on EGW larva. Fig. 6. *A. exertus* pupae: female (above) and male (below); (Source: Salle JL, Ramadan MK, Bernarr R. A new parasitoid of the *Erythrina* gall wasp, *Quadrastichus erythrinae* Kim (Hymenoptera: Eulophidae), Zootaxa. 2009; 2083: 19-26)

Eulophidae is considered monophyletic and comprises one of the largest families of parasitoid vespas with 332 genera and 5,416 species, which is subdivided into five subfamilies, being them Entiinae, Eulophinae, Entedoninae, Tetrastichinae and Opheliminae, Elasminae. Eulofídeos are insects that possess a large morphological variability, occurring in the tropics and temperate regions (Figures 16, 17, 18, 19, 20, 21 and 22) [12,13,14,15].

Figure 16 Subfamily Entiinae; (Source: https://bugguide.net/node/view/464489/bgimage)

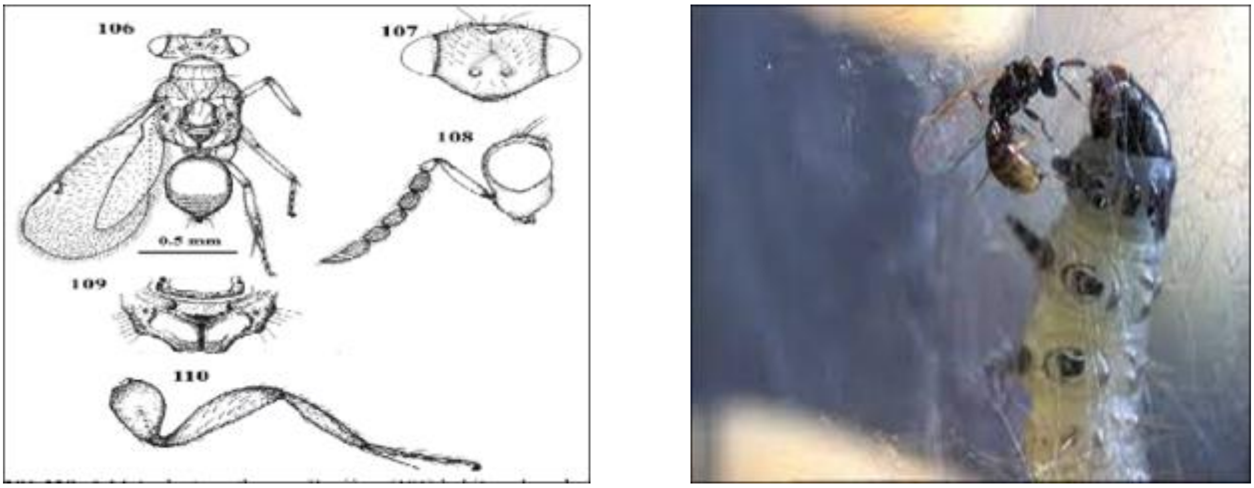


Figure 17 Subfamily Eulophinae (106) habitus, dorsal view, (107) head, frontal view, (108) head, lateral view, (109) propodeum, (110) hind leg; (Source: https://www.semanticscholar.org/paper/A-CONTRIBUTION-TO-THE-KNOWLEDGE-OF-THE-PARASITIC-OF Ubaidillah/f91ce70f2e8b78c0e29d0a94f4ffcc5df4180e2d)

Figure 18 Subfamily Entedoninae 1, habitus image; 2, dorsal view of mesosoma & head; 3, head frontal veiw; 4, malar sulcus; (Source: https://www.semanticscholar.org/paper/Description-of-two-new-species-of-subfamily-with-Jamali-Zeya/4e495e53a8cc69944b75f9472fea46edcfa03019/figure/0)

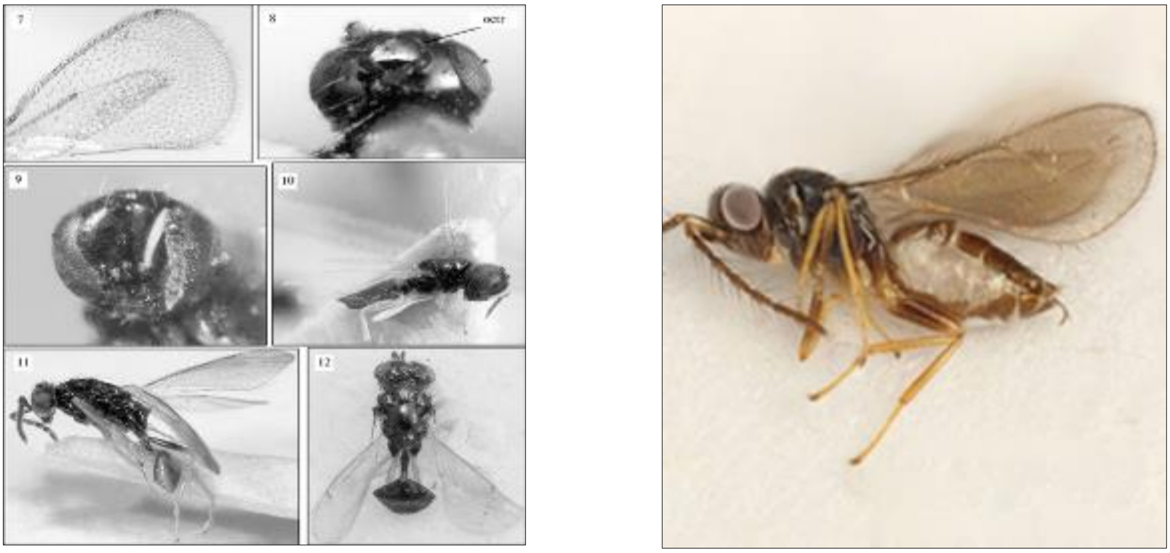


Figure 19 Subfamily Tetrastichinae wings; 8-10-D. (8-head in dorsal view; 9-head in frontal view; 10-habitus in lateral view); 11-scuta, holotype, habitus in lateral view; 12D. japonicus, holotype, habitus in dorsal view; octr, ocellar triangle; (Source: https://www.researchgate.net/figure/12-7-Derostenus-freemani-wings-8-10-D-persicus-8-head-in-dorsal-view-9-head_fig5_266878423)

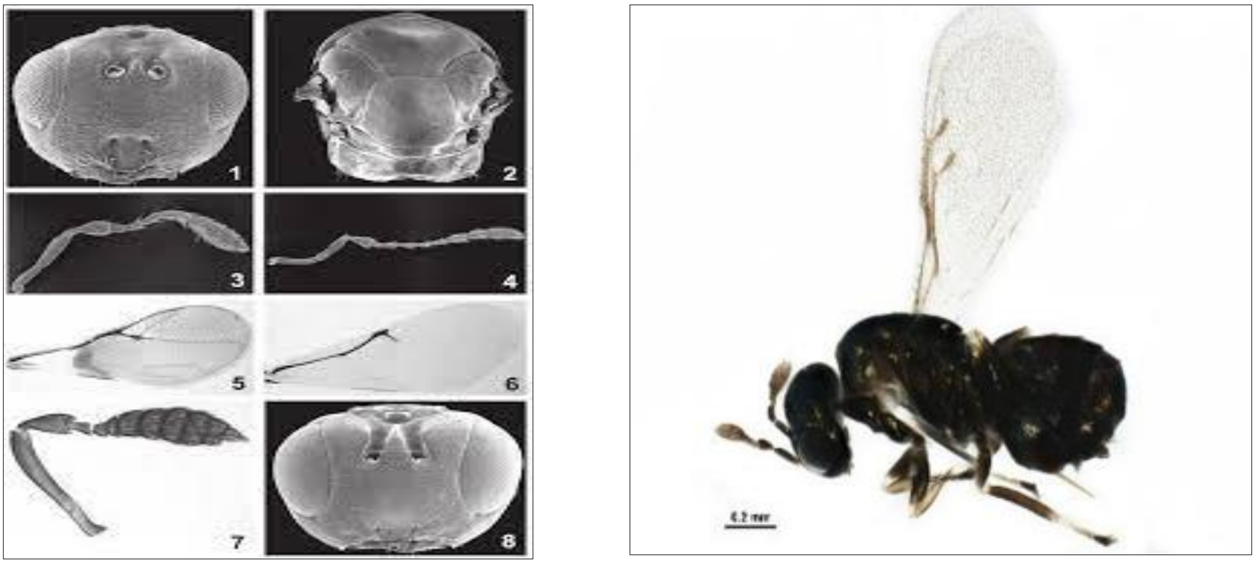


Figure 20 Subfamily Opheliminae (1-5): 1-head, frontal view; 2-thorax, dorsal view; 3-female antenna; 4-male antenna; 5-female forewing (6-8): 6-female forewing; 7-female antenna; 8-head, frontal view; (Source: https://www.researchgate.net/figure/8-Perthiola-bouceki-sp-nov-1-5-1-head-frontal-view-2-thorax-dorsal-view_fig2_242335337)

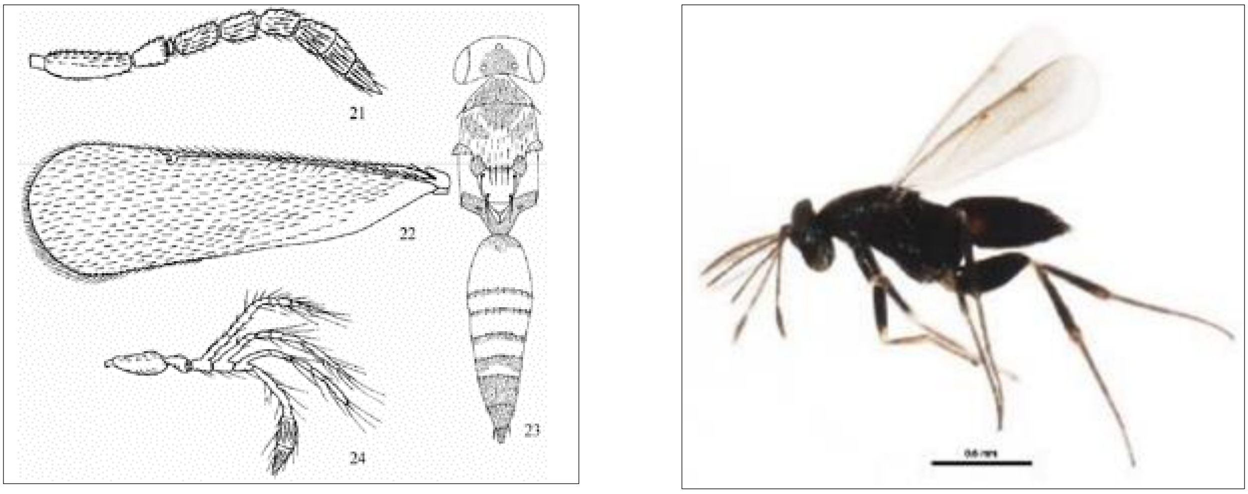


Figure 21 (21-23) female; (24) male [(21, 24) antenna; (22) fore wing; (23) coloration of body (mesosoma and metasoma); (Source: https://www.researchgate.net/figure/24-Elasmus-nikolskayae-Myartseva-et-Dzhanokmen-21-23-female-24-male-21-24_fig2_225591048)

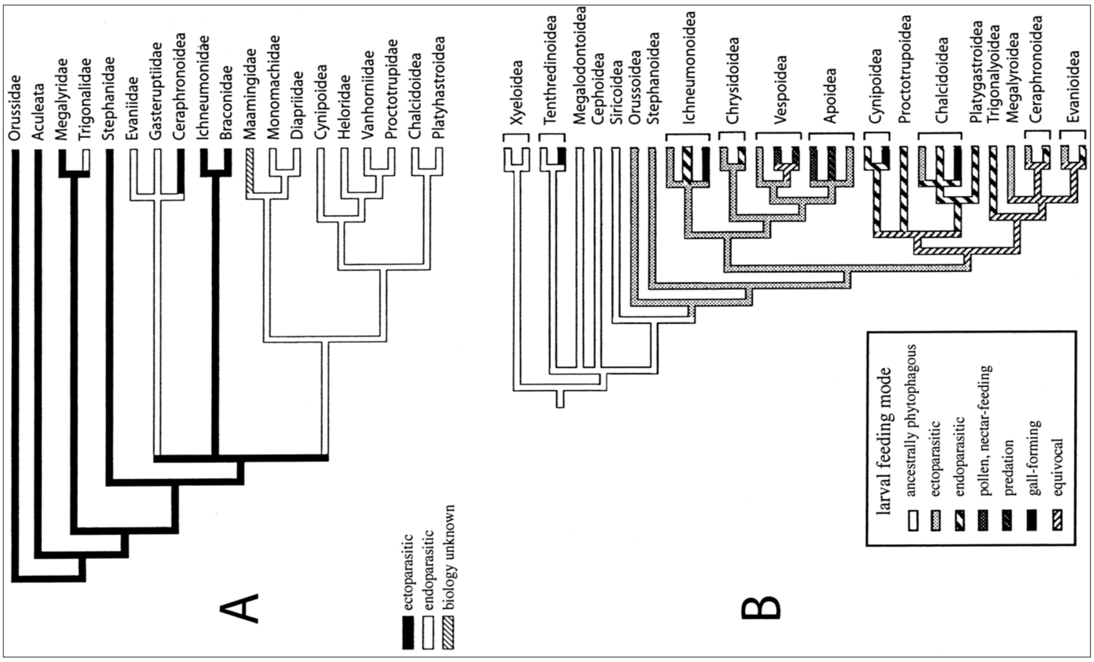


Figure 22 A Partial phylogenetic tree of Hymenoptera, based on analysis of combined morphological and molecular data, with transitions to ectoparasitism and endoparasitism indicated. (Reproduced with permission from Dowton and Austin; (Source: https://www.researchgate.net/figure/A-Partial-phylogenetic-tree-of-Hymenoptera-based-on-analysis-of-combined-morphological_fig4_8929584)

Objective

The aim is to describe the Family of the Eulophidae of economic importance in agriculture.

2. Material and methods

The method used to prepare this mini review was Marchiori 2021 methodology [16].

3. Studies conducted and selected

3.1. Study 1

Tetrastichus howardi (Olliff, 1893) (Hymenoptera: Eulophidae)

3.1.1. General characteristics

The adults of this insect are small wasps. about a millimeter in size and color metallic black, with elbowed antennae, one venation very reduced in its wings and a strong ovipositor that allows to pierce the chrysalises of its hosts and lay their small eggs inside. biology and habits *T. howardi* Hymenoptera gregarious pupal parasitoid of *Diatraea saccharalis* Fabricius 1794, emerging an average of 150 adults per pupa, of which 75-80% are females (Figures 23 and 24) [17].

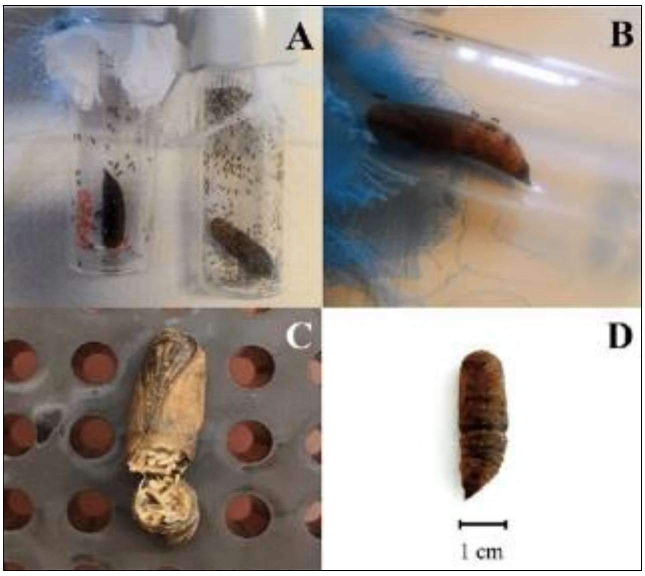


Figure 23 Adults of *Tetrastichus howardi* (Olliff, 1893) (Hymenoptera: Eulophidae) emerged from the *Oxydia vesulia* (Cramer, 1779) (Lepidoptera: Geometridae) (A), *T. howardi* females parasitizing *O. vesulia* pupae (B), larvae of *T. howardi* in development (C) and *O. vesulia* pupae after the parasitoid emergence (D); (Source: https://www.researchgate.net/figure/Adults-of-Tetrastichus-howardi-Hymenoptera-Eulophidae-emerged-from-the-Oxydia-vesulia_fig1_341597334)

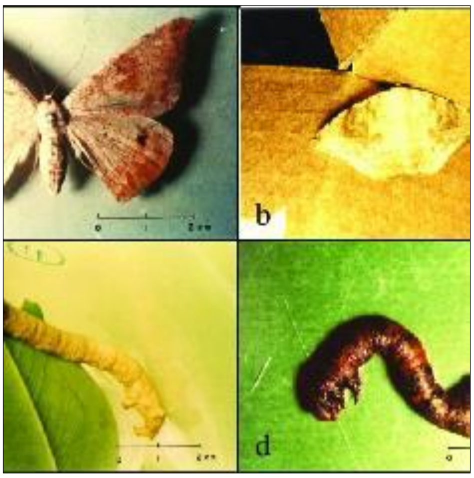


Figure 24 *Oxydia vesulia* (Cramer, 1779) (Lepidoptera: Geometridae): a, female; b, female in resting position; c, 5th stage sound caterpillar; d, 5th stage caterpillar killed by the action of *Bacillus thuringiensis* var. kurstaki (Berliner, 1915) (Bacillaceae). Noticing dark spots caused by the bacillus; (Source: https://www.researchgate.net/figure/Oxydia-vesulia-a-femea-b-femea-em-posicao-de-repouso-c-lagarta-sadia-do-5-o_fig2_265249671)

A female lay approximately 48 eggs. Your cycle length is 14 to 18 days at a temperature of 25 to 27°C, males are born on average one day before females and mating occurs immediately after their emergence. The earlier emergence of males is related to their smaller size (Figure 25) [17].

Figure 25 *Tetrastichus howardi* (Olliff, 1893) emerging from the pupa; (Source: https://repositorio.senasa.gob.pe:8443/bitstream/SENASA/275/1/2014_Salcedo_FT-11-T.howardi.pdf)

3.1.2. Mode of action

They are endoparasitoids mainly of Lepidoptera pupae, used in control biological control of agricultural pests in various countries. *Tetrastichus howardi* is usually shipped in parasitized pupae, average 32 to 40 pupae by transparent plastic containers with a capacity of one liter in whose base place chopped paper to avoid the blow and with threads of honey so that the adults if they emerged on the road. In addition, the lid is sealed around with parafilm tape [17].

These jars guarantee sufficient airtightness to prevent leaks, since they contain emergence, courtship and mating of adults will take place. It is not advisable to group them in excess because the overcrowding of the parasitoids, once that emerge, can increase their mortality [17].

3.2. Study 2

Figure 26 Embryonic development of *Palmistichus elaeisis* Delvare & LaSalle, 1993. A, newly laid eggs; B, egg with developing larva (L); C, egg with fully developed larva; D, hatched larva (48 h.); E, newly hatched larva; F, typical 1st instar larvae (72 h.); (Source: https://www.scielo.br/j/rbent/a/Jnm5jtVHBcLj4Ng4rPKLqcS/?lang=pt#)

This work aimed to morphologically characterize the immature stages of *Palmistichus elaeisis* Delvare & LaSalle, 1993 and evaluate its development on pupae of five lepidopteran species reared on an artificial diet. The research was carried out at the Biological Control Laboratory of the Department of Entomology, Phytopathology and Agricultural Zoology of the "Luiz de Queiroz" Higher School of Agriculture, University of São Paulo, in Piracicaba, São Paulo [18].

The eggs are hyaline, smooth, typically hymenopteriform and have a narrower anterior region. The incubation period lasted approximately 48 hours in the different hosts. The 1st instar larvae are apodous with a transparent cuticle, hymenopteriform shape with 12 segments; the larvae of the 2nd, 3rd and 4th instars (5 to 10 days) have a whitish color and well-defined segmentation. The larval stage lasted 8.04 ± 0.17 days in the hosts used (Figure 26).

Prepupa is white and with pigmented appendages. The pre-pupal stage was approximately 24 hours in all tested hosts, and the elimination of meconium was observed after the last larval instar. The pupal period was 9.8 ± 0.17 days. Until sexual differentiation, the coloration of the pupae is whitish and with red eyes. The pupae of females are generally larger in length than those of males and from the 14th day of development, when the integument and eyes darken, differentiation between females (darkening of the ovipositor) and males (ventral plate on the scape). The dimensions of the developmental stages of *P. elaeisis* in the different tested hosts were recorded (Figure 27).

Figure 27 Immature forms of *Palmistichus elaeisis* Delvare & LaSalle, 1993. A, larva; B, pre-pupae; C, pupae; (Source: https://www.scielo.br/j/rbent/a/Jnm5jtVHBcLj4Ng4rPKLqcS/?lang=pt#)

Post-embryonic development has four larval instars; the number of instars was determined by the frequency distribution of the head capsule measurements of the larval stages of *P. elaeisis*, with the coefficient of determination being 99% and the Dyar constant (K), 1.40. It was found that the host species (Lepidoptera) does not influence the number of instars [18].

3.3. Study 3

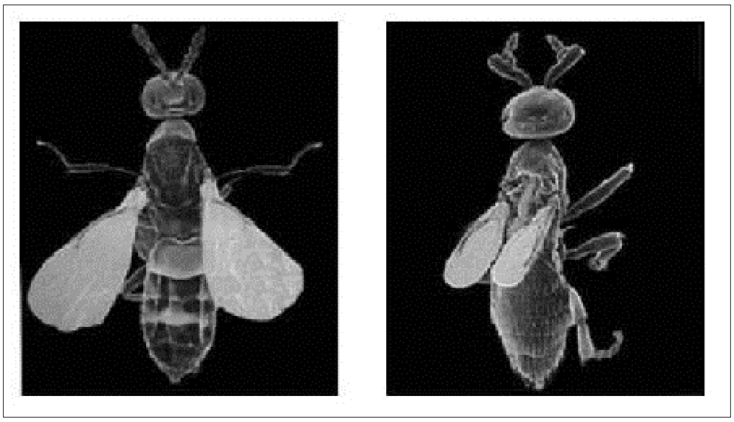


Figure 28 Sexes of *Melittobia digitata* Dahms 1984. The female is on the left, male on the right; (Source: https://www.researchgate.net/figure/Sexes-of-M-digitata-The-female-is-on-the-left-male-on-the-right_fig2_242121220)

Melittobia digitata Dahms 1984 are tiny wasps about 1.5 mm long and they show a remarkable plasticity of behavior. Uninseminated females can survive and eventually produce progeny of both sexes even in the absence of preferred hosts. They exhibit arrhenotokous parthenogenesis, and are gregarously developing ectoparasitoids of a wide range of hosts (pupae and prepupae) in various insect orders including Coleoptera, Lepidoptera, Diptera, and Hymenoptera (Figures 28, 29 and 30) [19,20].

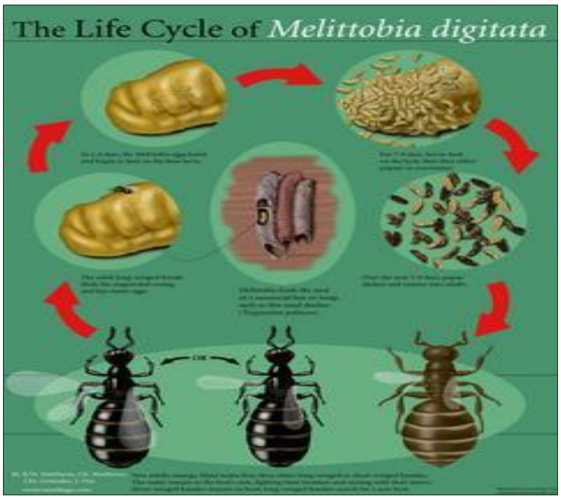


Figure 29 *Melittobia digitata* Dahms 1984 life cycle; (Source:https://www.discoverlife.org/nh/tx/Insecta/Hymenoptera/Chalcidoidea/Eulophidae/Melittobia/digitata/)

After mating, females produce a clutch of progeny in which about 95 % of the offspring are females. *Melittobia* displays pronounced sexual dimorphism with males being blind and flightless, very rapid life cycle (about 25 days). Males produce a pheromone that attracts females, and they have an elaborate courtship ritual. If males contact other males, they engage in ferocious battles. They are excellent organisms for laboratory experiments and are also valuable as classroom animals to aid in the study of genetics, ecology, biology and evolution [19,20].

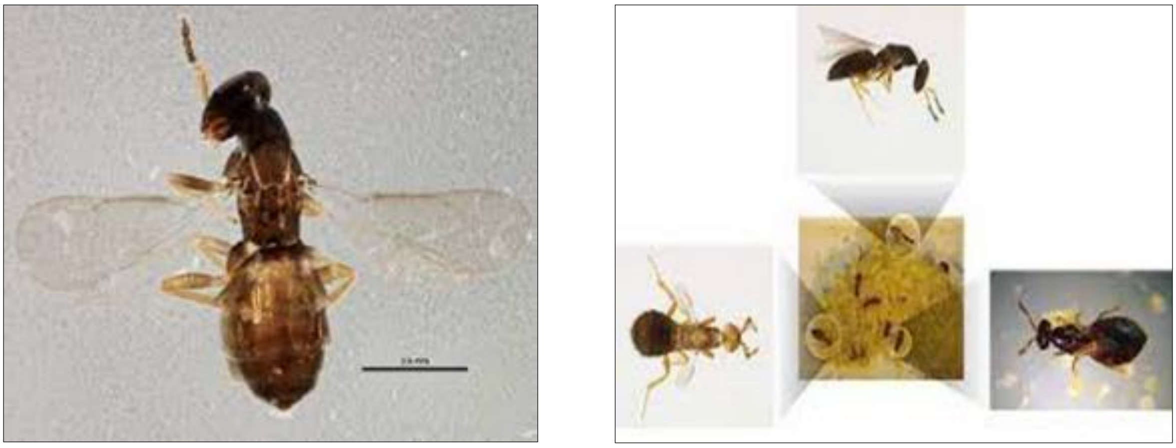


Figure 30 *Melittobia digitata* Dahms 1984

(Source: https://v3.boldsystems.org/index.php/TaxBrowser_Taxonpage?taxid=930393)

Distribution: Michoacán, Chiapas, Veracruz, North Carolina, U.S., it can be found also in Mexico and Canada. It is quite common in the southeastern U.S. Hosts: *Anastrepha ludens* (Loew, 1873). This is the first record of any *Melittobia* species parasitizing fruit flies (*Anastrepha* spp.). It is possible that the *M. digitata* specimens were originally behaving as hyperparasitoids of other parasitic wasps attacking the fruit flies [19,20].

3.4. Study 4

Creation of the alternative host *Anticarsia gemmatalis* Hübner, 1818. The rearing was maintained at 25 ± 2 ºC, relative humidity of 70 ± 10%, photophase of 14 hours and started with eggs from the LCBI stock. These eggs were placed inside Petri dishes (10.0 x 2.5 cm) and the newly emerged caterpillars were placed in 1,000 mL plastic pots containing artificial diet. Pupae of *A. gemmatalis* were placed in screened cages (30 x 30 x 30 cm), lined internally on their sides with bond paper, as a substrate for oviposition, and the emerged adults were fed with 10% aqueous honey solution (Figure 31) [21].

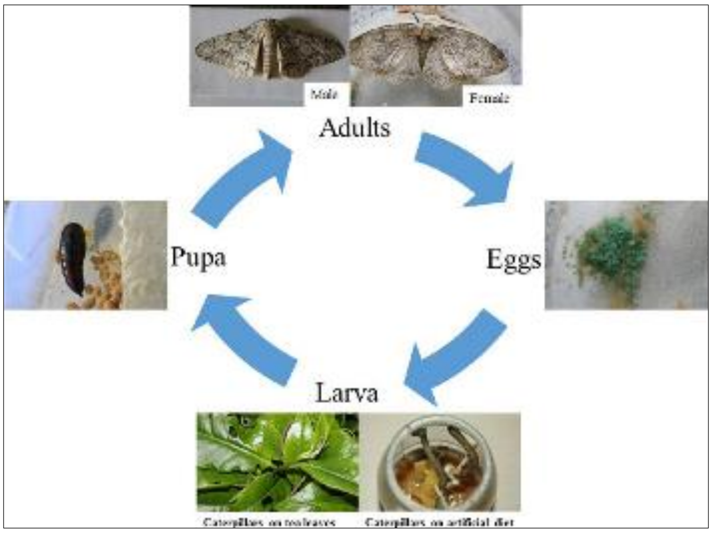


Figure 31 *Anticarsia gemmatalis* Hübner, 1818, life cycle; (Source: https://www.semanticscholar.org/paper/First-Attempt-of-Complete-Rearing-of-Tea-Looper%2C-on-Prasad-Mukhopadhyay/18b60a59cd97cf14b27dee1b62496ba2b922dcc7)

Breeding of *Palmistichus elaeisis* Delvare & LaSalle, 1993. Adults of *P. elaeisis* were kept in glass tubes (2.5 x 17.0 cm), labeled, covered with cotton, containing honey droplets to feed the parasitoids. For rearing maintenance, *A. gemmatalis* pupae aged 24 to 72 hours were exposed to parasitism for 24 hours at 25 ± 2 ºC, relative humidity of 70 ± 10% and photophase of 12 hours (Figure 32) [21].

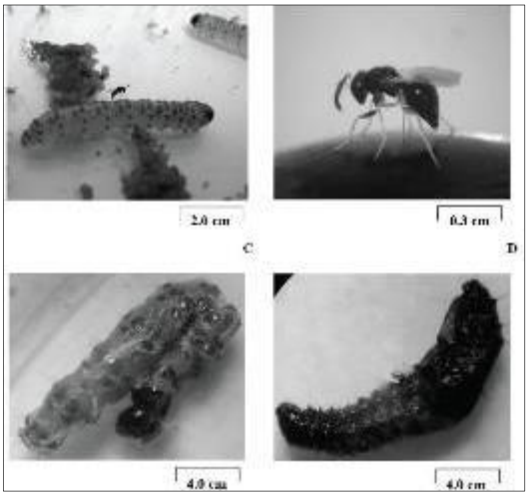
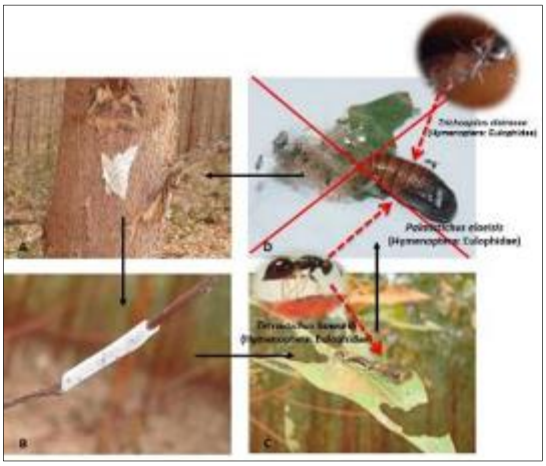


Figure 32 *Palmistichus elaeisis* Delvare & LaSalle, 1993 female parasitizing fifth instar caterpillar and pupa; (Source: https://bioone.org/journals/florida-entomologist/volume-98/issue-1/024.098.0164/Parasitism-and-Emergence-of-Tetrastichus-howardi-Hymenoptera--Eulophidae-on/10.1653/024.098.0164.full)

Experimental development. Thirty-six pupae of the alternative host, *A. gemmatalis*, weighing between 150 and 220 mg and with 24 to 48 hours of age were used in each replication grandis of two years old, in the upper, middle or lower thirds in the proportion of 33.33% (12 traps). After setting the traps, the plants were individually covered with a cage measuring 7.0 x 7.0 x 2.5 m, made of organza and bamboo fabric, and later released, 36; 72; 144; 288; 576 or 1,152 females of *P. elaeisis*, representing proportions of one, two, four, eight, 16 or 32 parasitoids per pupa of *A. gemmatalis*. Parasitism was allowed for 96 hours and, after this period, the traps with the pupae were removed and sent to the LCBI for evaluation of parasitism. As a control, 36 traps were placed in a tree under the same conditions as before, but without releasing *P. elaeisis*. During the experiment, the maximum and minimum temperatures were 19.15 ± 1.76 and 17.84 ± 1.70 ºC, respectively, and the mean relative humidity was 78.33 ± 1.34% [21].

3.5. Study 5

The Ministry of Agriculture, Livestock and Supply (Mapa) published, this Wednesday (21), two new Reference Specifications (ER) for the registration of the so-called “phytosanitary products with approved use for organic agriculture”, which can be used in any cropping system. With today's publication, Mapa reaches the historic mark of 50 ER and creates more opportunities for interested companies to make new products available on the market in a short time through a simplified registration process (Figures 32A, 32B, 32C, 33 and 34).



A B

Figure 32A *Trichospilus diatraeae* Cherian & Margabandhu, 1942 (Hymenoptera: Eulophidae) and *Trichospilus elaeisis* Delvare and LaSalle, 1993 (Hymenoptera: Eulophidae) **32B** *Trichospilus diatraeae* Cherian & Margabandhu parasitoide of female from pupa of *Anticarsia gemmatalis* Hübner, 1818 (Lepidoptera: Noctuidae) on sugracane, Brazil; (Source: Photo & © Heraldo Negri de Oliveira jr. and http://lecobiol.com.br/na-midia/)

Figure 32C *Anticarsia gemmatalis* Hübner, 1818 (Lepidoptera: Noctuidae); (Souce: https://slidetodoc.com/aplicaes-do-cultivo-de-clulas-animais-protenas-recombinantes/)

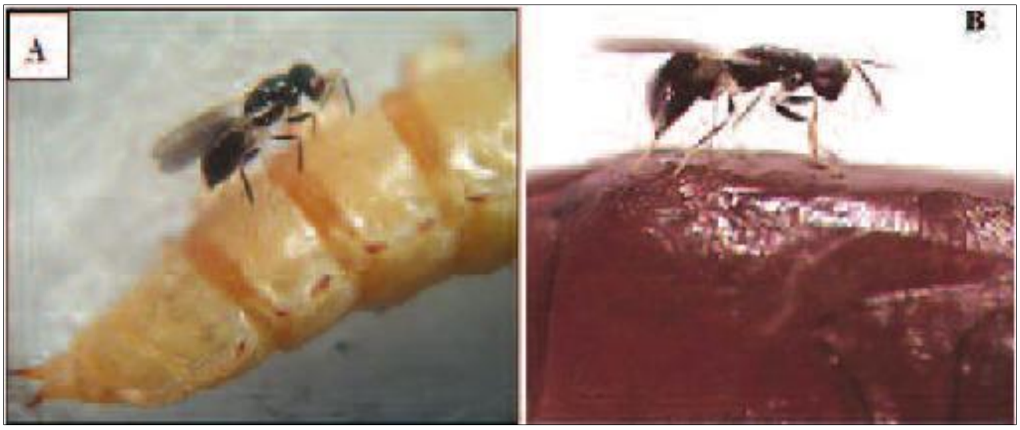


Figure 33 Females of *Palmistichus elaeisis* Delvare and LaSalle, 1993 (Hymenoptera: Eulophidae) parasitizing pupae of (A) *Tenebrio molitor* (Linnaeus, 1758) (Coleoptera: Tenebrionidae) (B) *Anticarsia gemmatalis* Hübner, 1818 (Lepidoptera: Noctuidae) (Lepidoptera: Noctuidae); (Source: https://www.agrolink.com.br/problemas/besouro_2963.html)

Figure 34 *Tenebrio molitor* (Linnaeus, 1758) (Coleoptera: Tenebrionidae); larvae, pupa and adult; (Source: https://www.agrolink.com.br/problemas/besouro_2963.html)

Figure 35 *Thyrinteina arnobia* (Stoll, 1782) (Lepidoptera, Geometridae); larvae, pupae and adults; (Source: https://www.infoteca.cnptia.embrapa.br/bitstream/doc/870104/1/DOC2010105.pdf)

The two new active ingredients are the biological control agents *Trichospilus diatraeae* Cherian & Margabandhu, 1942 (Hymenoptera: Eulophidae) is a pupal endoparasitoid (ER 49) and *Palmistichus elaeisis* (Delvare e LaSalle, 1993) (Hymenoptera Eulophidae) (ER 50), which act on a target that is also new to the biological ER, *Thyrinteina arnobia* (Stoll, 1782) (Lepidoptera, Geometridae) is behaving as the most important pest, known as brown-colored caterpillar. This species feeds on eucalyptus leaves and is considered one of the main pests of these crops in Brazil due to the intense defoliation it causes, reaching up to 100% of the planting (Figure 35).

Products registered based on ER 49 and 50 may be used not only in eucalyptus, but in any culture with occurrence of *T. arnobia*. In the case of ER 49, the products can also be used to control *Diatraea saccharalis* (Fabricius 1794) (Lepidoptera: Crambidae), a borer that is considered the most important in sugarcane and also attacks crops such as rice and corn.

3.5.1. New targets and formulation

Figure 36 *Myzus persicae* (Sulzer, 1776) (Hemiptera: Aphididae) (light green aphid); (Source: https://www.agrolink.com.br/problemas/pulgao-verde_327.html)

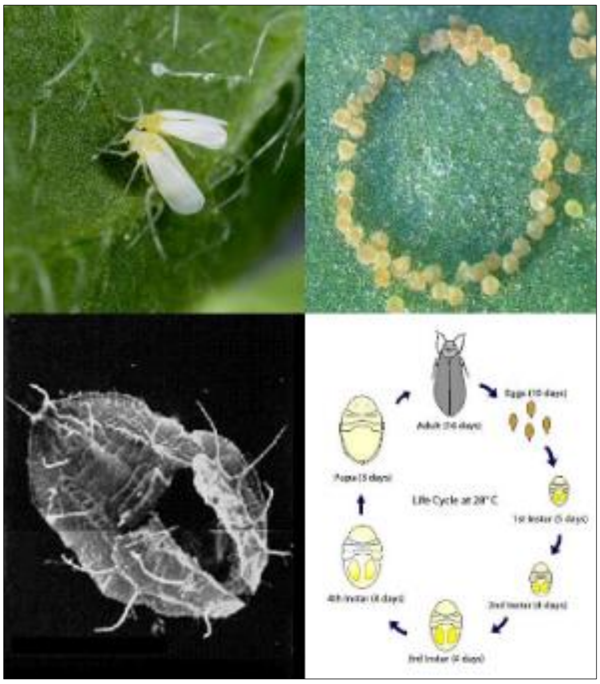
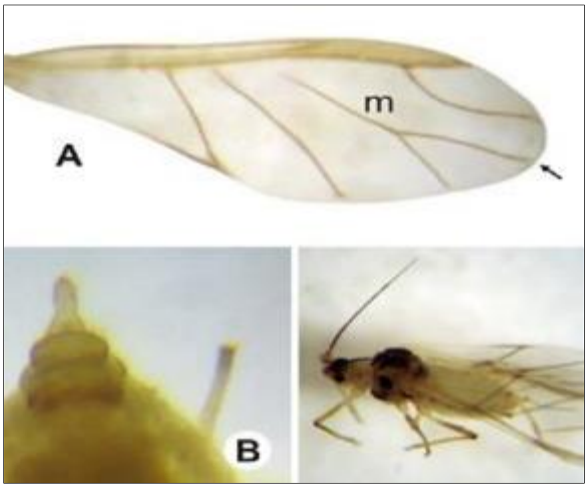


Figure 37 The whitefly to *Bemisia tabaci* (Genn. 1889) (Hemiptera: Aleyrodidae). From top to bottom and from left to right: male (smaller) and female adults feeding on a leaf; circular pattern of eggs laid by *B. tabaci*; exuvia of *Bemisia* that is left after adult emergence; *Bemisia* life cycle; (Source: https://www.researchgate.net/figure/The-whitefly-Bemisia-tabaci-From-top-to-bottom-and-from-left-to-right-male-smaller_fig1_283416534)

Thyrinteina arnobia was not the only new biological target in the specifications of Ordinance No. 363. In the republication of ER 21, for the biological agent *Chrysoperla externa*, Hagen, 1861 (Neuroptera: Chrysopidae) (Predator), there was a 130% increase in the number of targets, which jumped from three to seven. In addition to *Bemisia tabaci* (Genn. 1889) (Hemiptera: Aleyrodidae) biotype B (whitefly), *Myzus persicae* (Sulzer, 1776) (Hemiptera: Aphididae) (light green aphid) and *Schizaphis graminum* (Rondani, 1852) (Homoptera, Aphididae) (green cereal aphid), which already appeared in the original publication, four more were added, all unpublished in ER: *Macrosiphum euphorbiae* (Thomas, 1878) (Homoptera, Aphididae) (Solanaceae aphid), *Macrosiphum rosae* (L., 1758) (Homoptera, Aphididae) (purple rose aphid), *Rhodobium porosum* (Sanderson, 1901) (Hemiptera: Aphididae) (yellow rose aphid) and *Aphis gossypii* Glover, 1877 (Hemiptera: Aphididae) (cotton aphid) (Figures 36, 37, 38A and 38B).

A.



B.

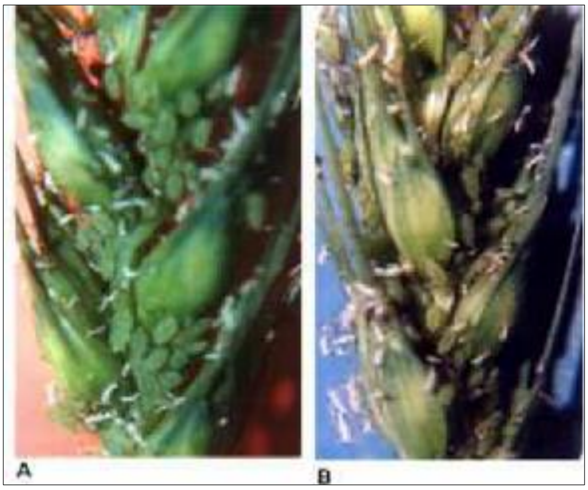


Figure 38A *Schizaphis graminum* (Rondani, 1852). Detail of the wing showing a branched middle vein. **Figure 38**B Green bug *S. graminum* attacking on wheat spikes; (Source: https://www.researchgate.net/figure/Green-bug-Schizaphis-graminum-Rond-attacking-on-wheat-spikes_fig1_263662789)

With some requests already under analysis, *C. externa* should inaugurate the use, in the country, of products registered with predatory insects for the biological control of all seven targets of the new ER 21, which until now had not been contemplated with this category of protection. Control agents (predatory insects)", points out Breitenbach (Figures 39, 40, 41, 42 and 43).

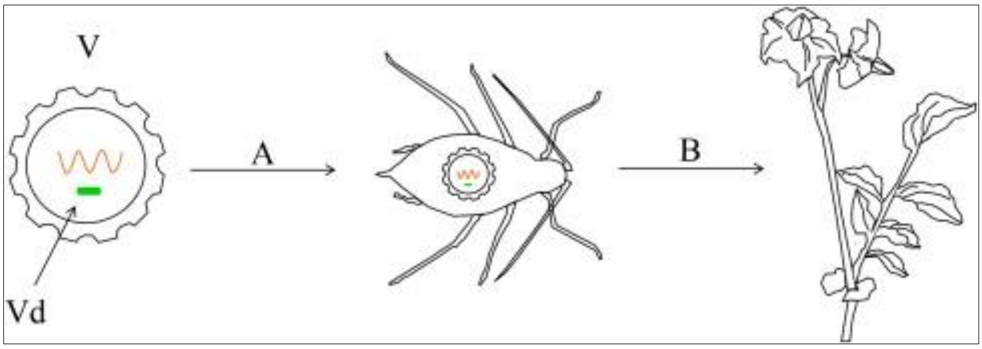


Figure 39 (A) Uptake of the viroid–virus system by an insect. (B) Insect-mediated transmission of the viroid–virus system between plants. Vd = viroid, V = icosahedral virus particle; (Source: https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/macrosiphum-euphorbiae)

Another republished ER was number 19 of the fungus *Trichoderma asperellum* (Fungi) isolated URM-5911. The main changes were due to the inclusion of a new deposit collection (Collection of Cultures of Microorganisms from Bahia – CCMB, isolated CCMB605P) and more substances in the list of authorized "other ingredients". In this case, the biological targets remained the same as in the previous version, but the new substances paved the way for the registration of a type of formulation that had not yet appeared in ER: Powder for dry seed treatment (DS).

Figure 40 Potato aphid: *Macrosiphum euphorbiae* (Thomas, 1878) (Homoptera, Aphididae) wingless females and juveniles; (Source: https://www.mindenpictures.com/stock-photo-potato-aphid-macrosiphum-euphorbiae-wingless-females-and-juveniles-naturephotography-image80113055.html)

Figure 41 True bugs, cicadas and aphids (Aphididae) *Macrosiphum rosae* (L., 1758) (Homoptera, Aphididae)- rose aphid; (Source: https://www.southernalpsphotography.com/Wildlife/Insects/True-bugs-cicadas-and-aphids/Aphididae/Macrosiphum-rosae/)

Figure 42 *Rhodobium porosum* (Sanderson, 1901) (Hemiptera: Aphididae) (yellow rose aphid); (Source: https://www.flickr.com/photos/koppert/albums/72157604456137205/)

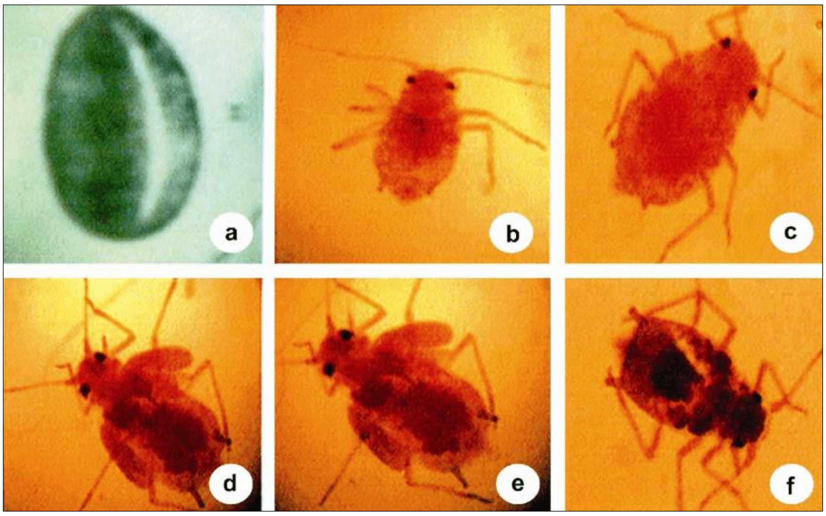


Figure 43 Developmental stages of the aphid, *Aphis gossypii* Glover, 1877 (Hemiptera: Aphididae) (cotton aphid). (The). The eggs. (b) The first instar nymph. (c) The second instar nymph. (d) The third instar nymph. (e) The fourth instar nymph and (f) The adult; (Source: https://www.researchgate.net/figure/Developmental-stages-of-the-aphid-A-gossypii-Glover-a-The-eggs-b-The-first_fig1_326626253)

3.5.2. Eucalyptus

Eucalyptus is one of the most used forest species in the formation of planted forests. In addition to capturing carbon dioxide (CO2) from the atmosphere, which helps to reduce the effects of global warming (since CO2 is a greenhouse gas), planted forests provide wood for various purposes such as cellulose, paper, charcoal, civil construction, furniture and others, relieving the pressure on native forests (Figure 44).

Figure 44 *Eucalyptus* (Myrtaceae; Juss., 1789); (Source: https://bernadetealves.com/2021/01/10/eucalyptus-deglupta-a-obra-de-arte-da-natureza/)

Forest products and the sugar and alcohol complex (especially sugar) were among the top five sectors in agribusiness exports, which recorded a record US$ 14 billion in May 2021, with Brazil occupying the 1st position in the ranking of pulp exporting countries [22].

3.6. Study 6

Tetrastichus howardi (Olliff, 1893) (Hymenoptera: Eulophidae) is a gregarious endoparasitoid, parasitoid of pupae of several families of lepidopterans, including: Crambidae, in the case of *Diatraea saccharalis* (Fabricius 1794) (Lepidoptera: Crambidae), with the species *Helicoverpa armigera* (Hübner, 1805) (Lepidoptera Noctuidae) and Plutellidae, especially with *Plutella xylostella* (L., 1758). (Figures 45A and 45B).

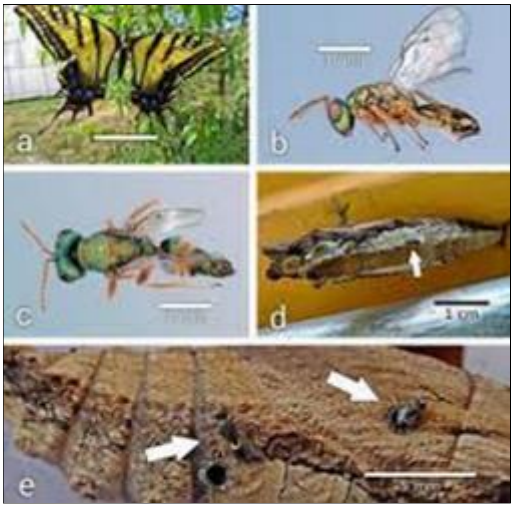


Figure 45 A adult of *Tetrastichus howardi* (Olliff, 1893) (Hymenoptera: Eulophidae). **Figure 45** B Adults of *T. howardi* emerged from the *Oxydia vesulia* (Cramer, 1779) (Lepidoptera: Geometridae) pupae (A), *T. howardi* females parasitizing *O. vesulia* pupae (B), larvae of *T. howardi* in development (C) and *O. vesulia* pupae after the parasitoid emergence (D); (Source: https://www.researchgate.net/figure/Life-cycle-of-Spodoptera-frugiperda-under-controlled-laboratory-conditions_fig1_283767237)

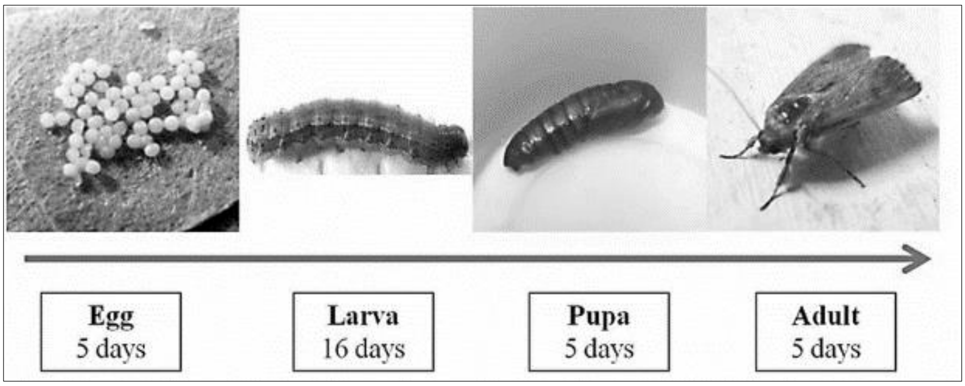


Figure 46 Life cycle of *Spodoptera frugiperda* Smith, 1797 (Lepidoptera: Noctuidae) under controlled laboratory conditions; (Source: https://www.researchgate.net/figure/Life-cycle-of-Spodoptera-frugiperda-under-controlled-laboratory-conditions_fig1_283767237)

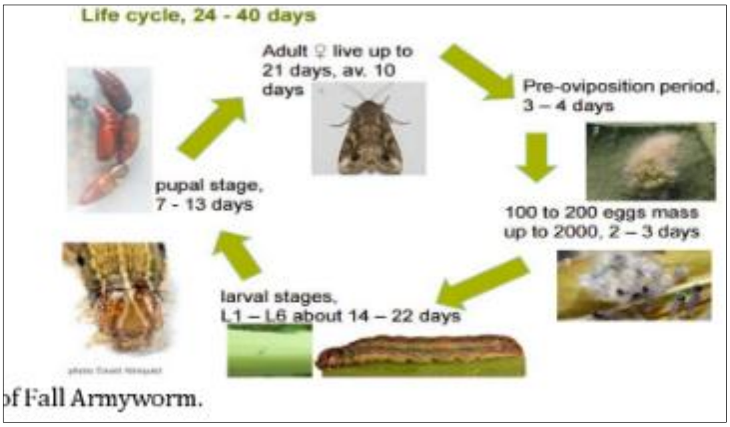


Figure 47 The lifecycle of fall armyworm without controlled conditions; (Source: https://www.semanticscholar.org/paper/Status-of-Fall-Armyworm-(Spodoptera-frugiperda)%2C-on-Assefa/96535357753d7d4fd37bb69d74db30dac78524d3/figure/1)

Tetrastichus howardi was collected in a sugarcane plantation in Dourados-MS, parasitizing pupae of *Diatraea* sp. (Lepidoptera: Crambidae) and *Spodoptera frugiperda* Smith, 1797 (Lepidoptera: Noctuidae) is considered the main pest of corn in the tropical and subtropical regions of the Americas. *Spodoptera frugiperda* caterpillars feed on the plant throughout its larval stage, initially scraping the youngest leaves from the plant, as they grow they begin to perforate the corn leaves, and may consume the plant completely (Figures 46, 47, 48, 49, 50 and 51).

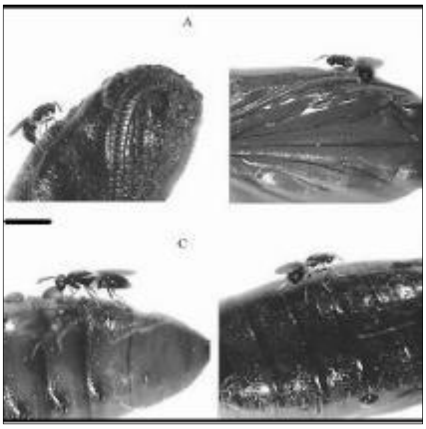


Figure 48 *Tetrastichus howardi* (Olliff, 1893) (Hymenoptera: Eulophidae) parasitizing *Spodoptera frugiperda* Smith, 1797 (Lepidoptera: Noctuidae);
(Source: https://www.researchgate.net/publication/247851617_Species_of_Lepidoptera)

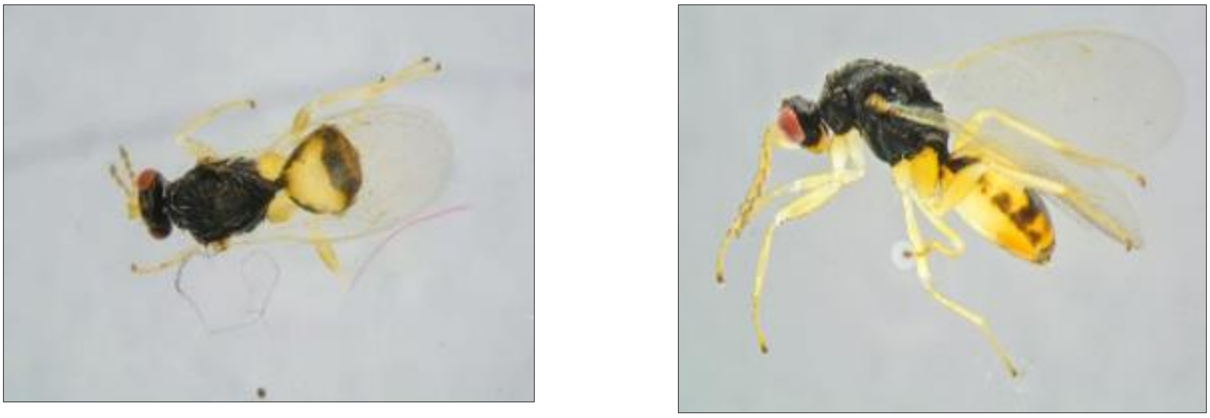


Figure 49 *Euplectrus furnius* Walker, 1843; (Source: https://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=156692)

Figure 50 Larvae of *Euplectrus furnius* Walker, 1843 on a noctuid caterpillar; (Source: http://taxondiversity.fieldofscience.com/2013/10/euplectrus.html)

Figure 51 Adult of *Euplectrus furnius* Walker, 1843 on a noctuid caterpillar in corn; (Source: https://ru.wikipedia.org/wiki/Euplectrus)

Brazil is among the largest corn producers in the world and the fall armyworm, *S. frugiperda* is the main insect pest of this crop in the country. Despite the importance of its natural enemies, there is still a lack of information about the species of parasitoids that attack this insect pest, such as larval parasitoids. This work reports *Euplectrus furnius* Walker (Hymenoptera: Eulophidae) parasitizing *S. frugiperda* larvae in corn in Brazil [23,24,25].

4. Conclusion

The biology of this family is extremely diversified, being known as ectoparasitoids or endoparasitoids of a wide range of hosts, from spiders, insect eggs, nematoids, mites, thrips and even other Hymenoptera, encompassing moreof 100 families in 10 orders of arthropods. They are important as biological control of certain pests.

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