Open Access Research Journal of
Multidisciplinary Studies
Journals home page: https://oarjpublication/journals/oarjms/
ISSN: 2783-0268 (Online)

(REVIEW ARTICLE)

Importance of the Encyrtidae Family (Insecta: Hymenoptera) for biological control

Carlos Henrique Marchiori *

Instituto Federal Goiano, Biology, Parasitology, Goiânia, Goiás, Brazil.

Open Access Research Journal of Multidisciplinary Studies, 2022, 03(02), 066–091

Publication history: Received on 19 April 2022; revised on 21 May 2022; accepted on 23 May 2022

Article DOI: https://doi.org/10.53022/oarjms.2022.3.2.0056

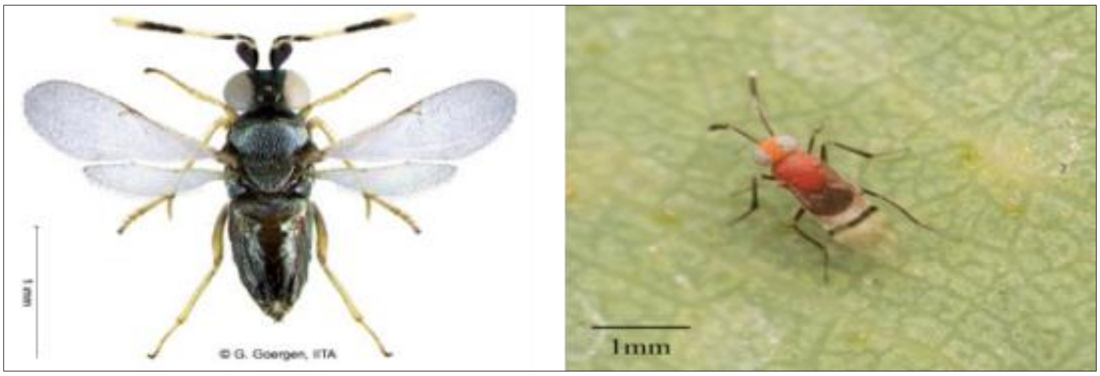
Abstract

The specificity of the host of many Encyrtidae remains uncertain, as some members of the family seem develop very well in different species of insects, while others appear to be parasites of a specific host. Most of the time, the species are oviposited in the host in its larval or nymph stage, but some species are known to oviposit in the pupa or even in adults. The larvae of most are parasitoids of Hemiptera, although they also have other ticks. His mini review is to demonstrate the importance of the Encyrtidae Family (Insecta: Hymenoptera) for biological control. With emphasis on conceptual and taxonomic aspects was carried out in the years 1940 to 2021. Only complete articles published in scientific journals and expanded abstracts presented at national and international were considered. Data were also obtained from platforms such as: Scielo Frontiers, Qeios, Pubmed, Biological Abstract, Publons, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic and Science.

Keywords: Ticks; Polyembryony; Taxonomy; Bioecology; Life cycle; Pests

1. Introduction

Encyrtidae is a cosmopolitan family and with the greatest structural and numerical diversity of Chalcidoidea: there are about of 745 genera and 3,825 described species. Of these, it is estimated that 565 species and approximately 180 genera can be found in the Neotropical Region. However, the group is little studied and These numbers can be much higher, since extrapolations carried out from the fauna of the Costa Rica which is considered as one of the best studied suggest that more than 15 thousand species only occur in the Neotropical Region (Figures 1, 2, 3 and 4) [1,2,3].



Source: https://es.wikipedia.org/wiki/Anagyrus

Figure 1 Specimens of Encyrtidae Family

* Corresponding author: Carlos Henrique Marchiori
Instituto Federal Goiano, Biology, Parasitology, Goiânia, Goiás, Brazil.

Copyright © 2022 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution Liscense 4.0.

Source: https://www.biodiversity4all.org/photos/6972519

Figure 2 Specimens of Encyrtidae Family: fontal, lateral, dorsal and ventral view

Source: https://www.inaturalist.org/taxa/69778-Encyrtidae/browse_photos

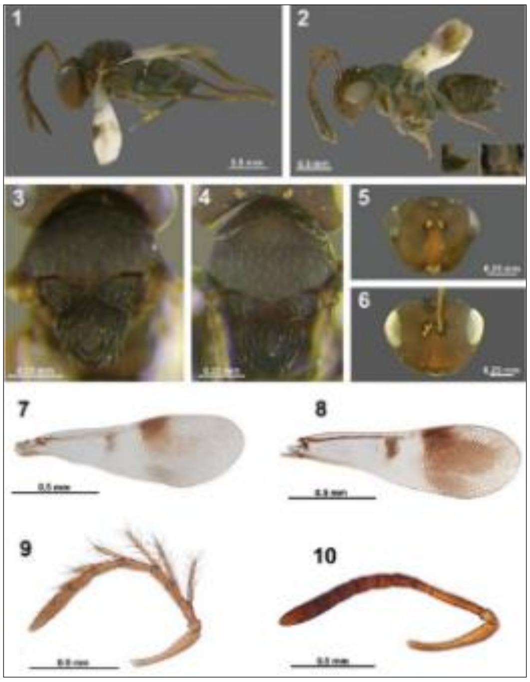
Figure 3 Specimens of Encyrtidae Family: side and back view

Source: https://www.inaturalist.org/taxa/69778-Encyrtidae/browse_photos

Figure 4 Front view showing antenna shape

1.1. Description

Adults in this family have between 0.3 and 0.5 mm, having a marginal vein very short on the forewing. Their habitats are the most varied, but are particularly diverse at low altitudes, in the canopy and in very droughts. It is easy to distinguish these wasps from others in the superfamily Chalcidoidea by details of wing venation, migration of the cerci into the metasoma with accompanying distortion of the tergites, and by an enlarged mesopleuron (Figures 5, 6, 7, and 8) [4,5].

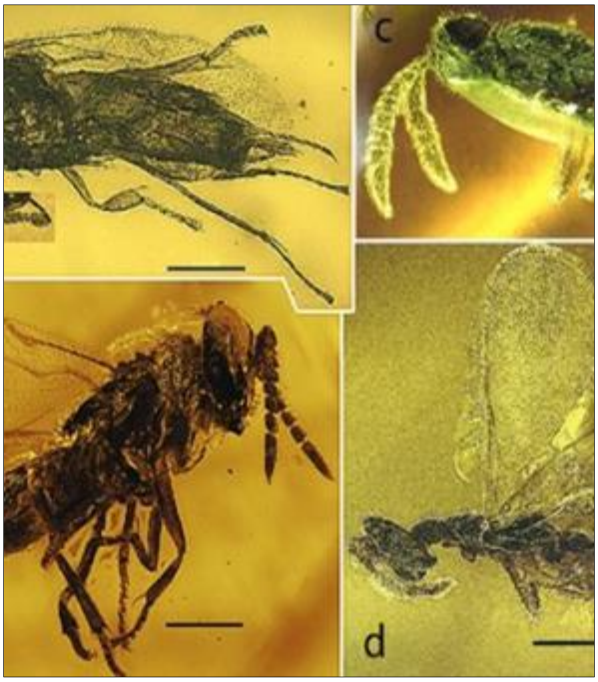


Source: https://jhr.pensoft.net/article/20742/

Figure 5 1 habitus (male) 2 habitus (female) (magnified apex of hypopygium, lateral and ventral view) 3 messoma (male, dorsal) 4 mesosoma (female, dorsal) 5 head (male, frontal) 6 head (female, dorsal) front) 7 fore wing (male, side) 8 fore wing (female, side) 9 antenna (male, side) 10 antenna (female, side)

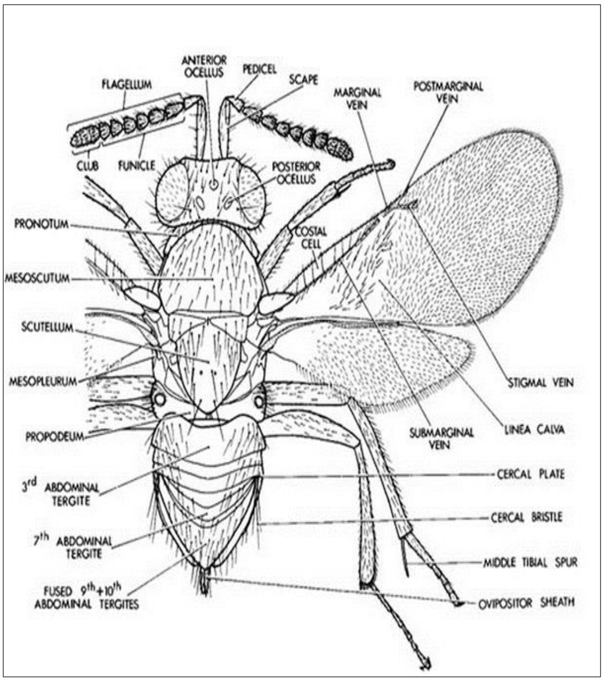
Source: file:///C:/Users/Sti/Downloads/47545%20(1).pdf

Figure 6 Female: 14, habitus in dorsal view; holotype female: 15, head and antenna; 16, fore wing; 17, mesosoma; 18 genitalia. Figures 19–22. *Anagyrus borrianensis* sp. nov., paratype male: 19, habitus in dorsolateral view; 20, antenna; 21, scale-like sensilla on F6 and clava; 22, fore wing



Source: https://www.researchgate.net/figure/a-A-rasnitsyni-holotype-dorsolateral-view-b-S-sakhalinica-holotype-lateral_fig2_347341006

Figure 7 ♀, holotype, and dorsolateral view. b, ♂, holotype, lateral view. c, ♂, holotype, lateral view. d, ♂, holotype, lateral view. Scale bar = 0.2 mm



Source: http://damiepak.blogspot.com/2015/04/wasp-families-encyrtidae-biocontrol.html

Figure 8 The anatomy of an Encyrtidae wasp

1.2. Biology

However, the specificity of the host of many Encyrtidae remains uncertain, as some members of the family seem develop very well in different species of insects, while others appear to be parasites of a specific host. Most of the time, the species are oviposited in the host in its larval or nymph stage, but some species are known to oviposit in the pupa or even in adults. The larvae of most are parasitoids of Hemiptera, although they also have other ticks. Their biology is highly variable (for example, some attack insect eggs or larvae, others ticks (Figure 9A) [6,7].

Source: Photos: Courtesy of CIP

Figure 9A The development stages of *Copidosoma koehleri* Blanchard, 1940*:* (A) larva, (B) pupa, (C) mummy with up to 72 individuals, and (D) adult

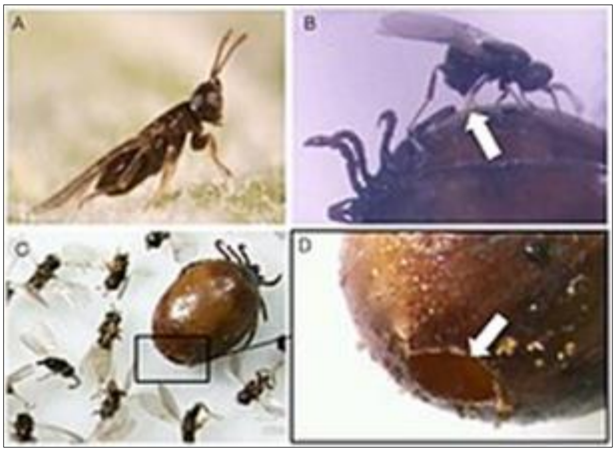
All are entomophagous insects: two out of three Encyrtidae are solitary endoparasitoids of hemipterans, mainly mealybugs of the genus *Leucanium*. The remainder parasitizes eggs, larvae or pupae of lepidopterans, leaf beetles, insects, mosquitoes and ticks. Copidosomatini are all Lepidoptera parasites (Figures 9B, 9C, 9D, 9E, 9F, 9G and 9H) [7,8].

Source: https://content.ces.ncsu.edu/oak-lecanium-scale

Figure 9B *Leucanium* (Hemiptera)

Source: https://pt.frwiki.wiki/wiki/Encyrtidae

Figure 9C Copidosomatini (Encyrtidae)



Source: https://en.wikipedia.org/wiki/Ixodiphagus_hookeri

Figure 9D *Ixodiphagus hookeri* Howard, 1908 (Hymenoptera: Encyrtidae): parasitoid of ticks

Source: https://www.sciencedirect.com/science/article/abs/pii/S1226861518306800

Figure 9E *Tachardiaephagus somervilli* (Mahdihassan, 1923) (Chalcidoidea: Encyrtidae), a biological control agent for the yellow lac scale, *Tachardina aurantiaca* (Cockerell, 1903) (Kerriidae: Tachardina) (Hemiptera: Coccoidea: Kerriidae)

Source: copyright Kent M. Daane

Figure 9F Female *Anagyrus pseudococci alongside* Girault (1915) remains of mealybug host

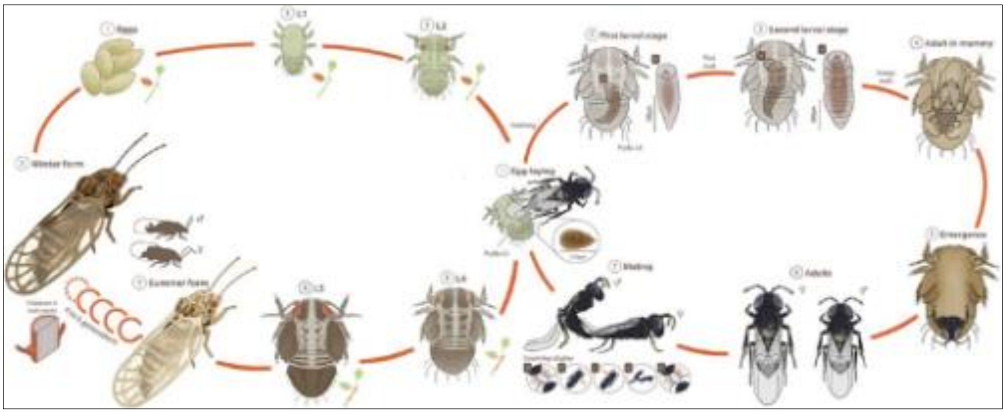
Source: https://www.agefotostock.com/age/en/Stock-Images/encyrtidae.html

Figure 9G Parasitoid wasp, *Encyrtus infelix* (Embleton, 1902), commercial biological control parasitoid laying her egg in scale insect host pests in protected crop

Source: https://www.researchgate.net/figure/Representatives-of-Encyrtidae-in-greenhouses-of-BG-PJSU-a-Anagyrus-pseudococci-b_fig6_283251462

Figure 9H Representatives of Encyrtidae in greenhouses of BG PJŠU: a) *Anagyrus pseudococci* (Girault, 1915), b) *Coccidoxenoides perminutus* (Girault, 1915), c) *Encyrtis aurantii* (Geoffroy, 1785), d) *Encyrtus infelix* (Geoffroy, 1785), e) *Leptomastix dactylopii* Howard, 1885, f) *Metaphycus helvolus* (Compere 1926). Scale bar: 1mm

Trechnites psyllae (Ruschka 1923) and *Prionomitus mitratus* (Dalman, 1820) (Encyrtidae) are endoparasites of *Psylla pyri* L. 1758 (Hemiptera: Psyllidae) (Figures 9I and 9J).



Source: https://onlinelibrary.wiley.com/doi/epdf/10.1002/ps.6517

Figure 9I *Prionomitus mitratus* (Dalman, 1820) (Encyrtidae) are endoparasites of *Psylla pyri* L., 1758 (Homoptera: Psyllidae) (pear psyllid)

1758 (Homoptera: Psyllidae) (pear psyllid). *Compercia merceti* (Compere, 1938) (Encyrtidae) parasites the cockroach *Supella longipalpa* (Fabricius, 1798) (Dyctioptera: Blateilidae). Some species are also hyperparasites of Encyrtidae, Aphelinidae, Cynipidae, Pteromalidae, Braconidae, Dryinidae. This is the case for *Syrphophagus mamitus* (Walker 1837) in Psyllid (Figures 9J, 9L and 9M).

Source: https://twitter.com/myrmecos/status/1374895233285111812

Figure 9J *Compercia merceti* (Compere, 1938) (Encyrtidae)

Source: https://bugguide.net/node/view/1155194

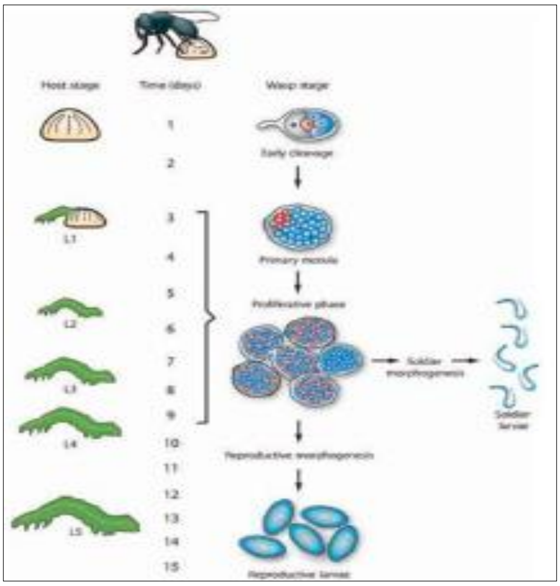
Figure 9K *Supella longipalpa* (Fabricius, 1798) (Dyctioptera: Blateilidae)

Source: Photographs by M. Nasser

Figure 9L Psylloid galls: 21, *Syzygium caryophyllatum* L. Alston (Family: Myrtaceae) leaf with galls; 22, *S. caryophyllatum*, galls cut open to show developing psylloids; 23, *Syzygium cumini* L. (Myrtaceae) leaf galls; 24, *Trioza jambolanae* Crawford, 1917 (Myrtales, Myrtaceae), adult; 25, *Garuga pinnata* Roxb. (Burseraceae), leaf galls

1.3. Reproduction and Life Cycle

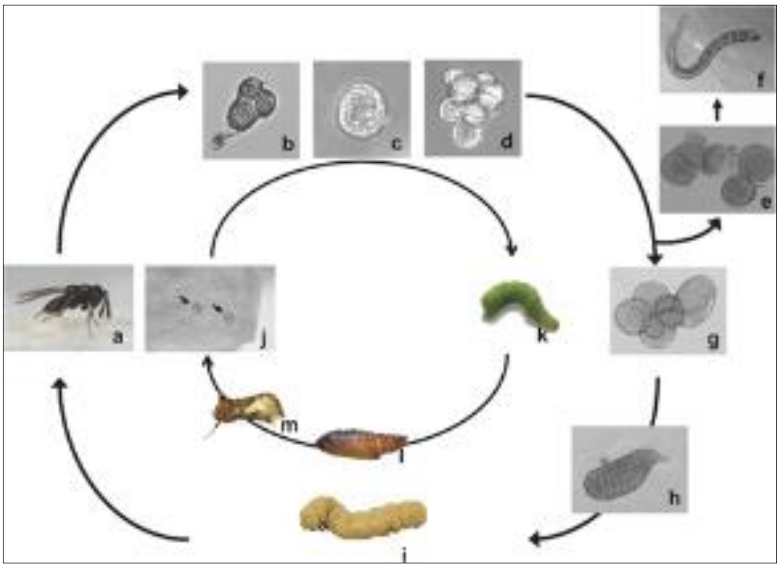
The egg is encirciform (tube) and often polyembryonic (fragmentation of the egg into several embryos **-** Some species exhibit a rare form of development called polyembryony, in which a single egg multiplies clonally, producing a large number of genetically identical individuals). Its cycle is from 5 to 50 days, fertility from 100 to 200 eggs. Adults lick the honeydew of homopterans. The sex ratio varies by species from 2 to 9 females per male. There is only one egg per host and all individuals of the same host are of the same sex (Figures 10, 11, 12, 13, 14 and 15) [8].



Source: http://what-when-how.com/insects/polyembryony-insects/

Figure 10 Development of the polyembryonic wasp *Copidosoma floridanum* (Ashmead, 1900) in its host *Trichoplusia ni* Hübner, 1803 (Lepidoptera: Noctuidae: Plusiinae). In the upper part of the figure, a wasp ovipositing one egg per host is shown. The main host stages are illustrated on the left with the duration of each stage indicated in days. The host egg hatches in 3 days followed by the development of the host larva through five instars from day 3 to 15. The egg undergoes early cleavage and forms a primary morula during the host egg stage

Even more remarkable is that some specimens are larger than others and behave like a soldier caste of eusocial insects, attacking other wasp larvae of the same or other species on the host. They die without reproducing, which is a form of "altruism" [8].



Source: https://www.researchgate.net/figure/The-life-cycle-of-Copidosoma-floridanum-C-floridanum-oviposited-its-egg-into-the-host_fig5_339192915

Figure 11 Life cycle of *Copidosoma floridanum* (Ashmead, 1900). Oviposition of an egg on the host (a). With the cleavages, the cells form the morula that is clonally divided and the polyembryos are formed around 60 h the embryos are formed in the host (d); segmentation and then soldier larvae develop via embryo (e and f). Each embryo forms fifth-instar larvae (g), reproductive larvae appear (h), the larvae emerge when the host insect reaches the second day of sixth-instar larvae, and the adult emerges from the mummy (i). j-m: Life cycle of *Thysanoplusia intermixta* (Warren, 1913) (Lepidoptera; Noctuidae; Plusiinae). (j) *T. intermixta* egg indicates black arrows. (k) Final (sixth) instar larvae. (l) Pupa, (m) adult

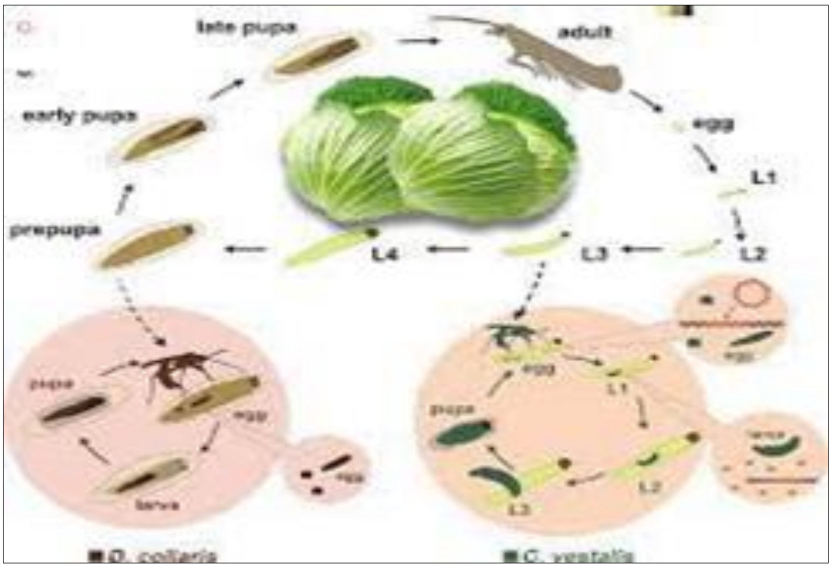
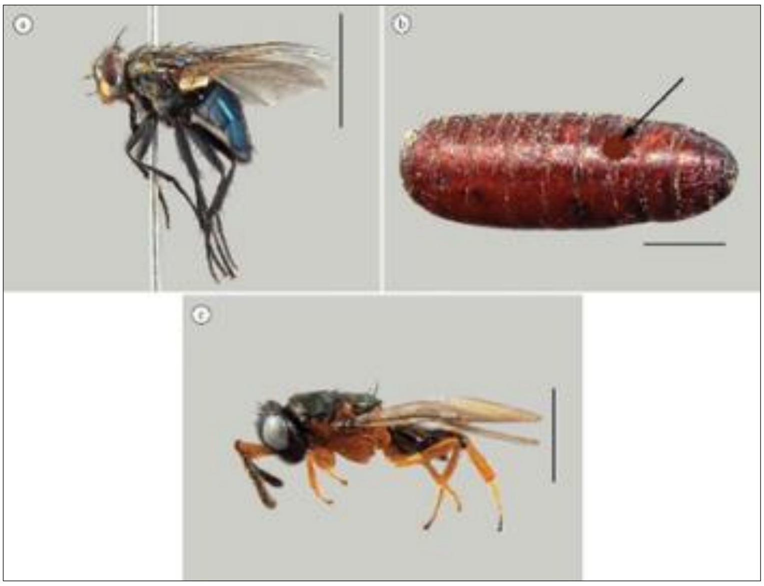


Figure 12 The life history of *Cotesia vestalis* (Haliday, 1834) bracovirus (CvBV) and *Diadromus collaris* (Gravenhorst, 1829) (Ichneumonidae *Diadromus vestalis* preferentially parasitizes second and third in star *Plutella xylostella* L., 1758 (Lepidoptera: Plutellidae) larvae (L2 and L3); and *D. collaris* parasitizes pupal stage hosts

Source: details: Canon MP-E 65mm 1-5x macro lens on a Canon EOS 20D; ISO 100, f/11, 1/200 sec, flash diffused through tracing paper

Figure 13 A young adult *Comperia merceti* (Compere, 1938) (Encyrtidae), a parasitoid wasp in the family Encyrtidae, emerges from the egg case of its cockroach host



Source: https://www.scielo.br/j/bjb/a/tt64LbsKQhJjJn9vBcDDgWm/?lang=en

Figure 14 (a) *Sarconesia chlorogaster* (Wiedemann, 1830) (Diptera: Calliphoridae) female, lateral view, scale bar = 5mm; (b). Pupae of *S. chlorogaster* parasitized by Ashmead, 1904. Black arrow indicates parasitoid emergence hole, scale bar = 2mm; (c). *Tachinaephagus zealandicus* Ashmead, 1904 (Hymenoptera: Encyrtidae), female, lateral view, scale bar = 1mm

Source: Jerinić-Prodanović D, Mihajlović L, Stojanović A. Parasitoids of jumping plant-lice (Psylloidea, Hemiptera) from the family Encyrtidae (Hymenoptera, Chalcidoidea) in Serbia. Zootaxa. 2019; 4577 (1): 29-50

Figure 15 In Parasitoids of jumping plant-lice (Psylloidea, Hemiptera) from the family Encyrtidae (Hymenoptera, Chalcidoidea) in Serbia. Figures 2–9. hosts. 2, Mummy of *Cacopsylla peregrina* (Förster, 1848) (Sternorrhyncha: Psylloidea: Psyllidae) (original); 3, Mummy of *Cacopsylla melanoneura* (Foerster, 1848) (Hemiptera) (original); 4, Mummy of *Cacopsylla picta* (Förster, 1848) (Homoptera, Psyllidae) (original); 5, Mummy of *Cacopsylla peregrina* (Foerster, 1848) (Psyllidae) (original); 6, Mummies of *Cacopsylla bidens* (Šulc., 1907) (Insecta: Hemiptera: Psyllidae) (original); 7, Mummy of *Cacopsylla pyrisuga* (Foerster, 1848) (Homoptera) (original); 8, Mummy of *Acizzia jamtonica* Kuwayama, 1908 (Homoptera: Psyllidae) (original); 9. Mummy of *Psylla alni* (Linné, 1758) (Hemiptera) (original)

1.4. Taxonomy

This family contains two subfamilies grouped around 460 genera for 3,600 described species: The Encyrtinae subfamily comprises 350 genera and 2,800 species.

Genera: *Acerophagus* Smith, 1880 (99), *Adelencyrtoides* Achikawa & Valentine, 1969 (14), *Adelencyrtus* Ashmead, 1900 (34), *Aenasius* Walker, 1846 (42), *Ageniaspis* Dahlbom, 1857 (16), *Aloencyrtus* Prinsloo, 1978 (20), *Allocerellus* Silvestri, 1915 (12), *Anagyrus* Howard, 1896 (269), *Anicetus* Howard, 1896 (51), *Anthemus* Howard, 1896 (22), *Aphycus* Mayr, 1876 (30), *Aschitus* Mercet, 1921 (20), *Bennettisca* Noyes, 1980 (10), *Blastothrix* Mayr, 1876 (28), *Blepyrus* Howard, 1898 (18), *Bothriothorax* Ratzeburg, 1844 (32), *Brethesiella* Porter, 1920 (18), *Cerapterocerus* Westwood, 1833 (11), *Cerchysiella* Girault, 1914 (31), *Cerchysius* Westwood, 1832 (14), *Cicoencyrtus* Noyes, 1980 (17), *Cirrhencyrtus* Timberlake, 1918 (10), *Clausenia* Ishii, 1923 (12), *Coccidencyrtus* Ashmead, 1900 (32), *Coelopencyrtus* Timberlake, 1919 (30), *Copidosoma* Ratzeburg, 1844 (186), *Copidosomopsis* Girault, 1915 (12), *Charitopus* Förster, 1856 (17), *Cheiloneurus* Westwood, 1833 (138), *Discodes* Förster, 1856 (41), *Diversinervus* Silvestri, 1915 (12), *Ectroma* Westwood, 1833 (11), *Echthroplexiella* Mercet, 1921 (31), *Encyrtus* Latreille, 1809 (87), *Ericydnus* Haliday, 1832 (29), *Ginsiana* Erdös & Novicky, 1955 (11), *Gyranusoidea* Compere, 1947 (43), *Habrolepis* Förster, 1856 (17), *Helegonatopus* Perkins, 1906 (13), *Hexacladia* Ashmead, 1891 (26), *Holcencyrtus* Ashmead, 1900 (10), *Homalotylus* Mayr, 1876 (62), *Isodromus* Howard, 1887 (24), *Ixodiphagus* Howard, 1907 (14), *Leptomastidea* Mercet, 1916 (22), *Leptomastix* Förster, 1856 (32), *Lohiella* Noyes, 1980 (14), *Mahencyrtus* Masi, 1917 (13), *Mayridia* Mercet, 1921 (34), *Meromyzobia* Ashmead, 1900 (25), *Metaphycus* Mercet , 1917 (449), *Metapsyllaephagus* Myartseva, 1980 (11), *Microterys* Thomson, 1876 (199), *Neastymachus* Girault, 1915 (13), *Neocladia* Perkins, 1906 (36), *Neococcidencyrtus* Compere, 1928 (20), *Oobius* Trjapitzin, 1963 (41), *Ooencyrtus* Ashmead, 1900 (296), *Parablastothrix* Mercet, 1917 (16), *Parablatticida* Girault, 1915 (14), *Paraphaenodiscus* Girault , 1915 (17), *Parechthrodryinus* Girault, 1916 (13), *Plagiomerus* Crawford, 1910 (10), *Prionomastix* Mayr, 1876 (27), *Prochiloneurus* Silvestri, 1915 (29), *Pseudectroma* Girault, 1915 (11), *Pseudencyrtus* Ashmead, 1900 (11), *Pseudococcobius* Timberlake, 1916 (12), *Psyllaephagus* Ashmead, 1900, (231), *Rhopus* Förster, 1856 (61), *Rhytidothorax* Ashmead, 1900 (19), *Syrphophagus* Ashmead, 1900 (83), *Tachinaephagus* Ashmead, 1904

(11), *Tetracnemoidea* Howard, 1898 (17), *Tetracnemus* Westwood, 1837 (33), *Trechnites* Thomson, 1876 (22), *Trichomasthus* Thomson, 1876 (57) and Z*aomma* Ashmead, 1900 (15).

The subfamily Tetracnemynae comprising 100 genera and 800 species. An extinct genus, *Archencyrtus*, has been described from the Middle Eocene in amber from Sakhalin (Sakhalin Island) in eastern Russia (Figure 16) [8,9].

Source: https://www.researchgate.net/figure/Late-Eocene-Encyrtidae-a-Sulia-glaesaria-Simutnik-2015-Danish-amber-b_fig7_347341006

Figure 16 Late Eocene Encyrtidae: a, *Sulia glaesaria* Simutnik, 2015, ♀, Danish amber. b, *Protocopidosoma kononovae* Simutnik, 2017, ♀, Danish amber. c and d, *Dencyrtus vilhelmseni* Simutnik, 2018, ♀, Danish amber. c, side view. d, dorsal view. and, *Rovnosoma gracile* Simutnik, 2015, ♀, Rovno amber. f, *Eocencyrtus zerovae* Simutnik, 2001, ♀, Rovno amber. Undescribed ♂, № 12, Danish amber. h, *Archaeocercus schuvachinae* Simutnik, 2018, ♀, Rovno amber. i, undescribed ♀, № 7, Danish amber. j, *Trjapitzion cylindrocerus* Simutnik, 2018, ♀, Rovno amber. k, *Eocencnemus sugonjaevi* Simutnik, 2002, ♀, Rovno amber. I, undescribed ♂, K-26710, Rovno amber. m, undescribed ♀, K-4994, Rovno amber

Objective

The objective of this mini review is to demonstrate the importance of the Encyrtidae Family (Insecta: (Hymenoptera) for biological control.

2. Methods

The method used to prepare this mini review was Marchiori 2021 methodology [10].

3. Studies conducted and selected

3.1. Study 1

3.1.1. Use in biological control

It is a family of the greatest importance in biological control because it is the most used: about fifty species have been used to date against mealybugs. *Anagyrus lopezi* (De Santis, 1964), (Hymenoptera: Tetracneminae) native to South America, was used on a large scale against the cassava mealybug *Phenacoccus manihoti* (Matile-Ferrero, 1997) (Homoptera: Pseudococcidae) in Africa. The use of *Ageniapis fuscicollis* (Dalman, 1820) (Encyrtidae) in orchards in the Soviet Union to control Yponomeute was successful (Figures 17, 18 and 19) [11].

Source: https://animaldiversity.org/collections/contributors/Grzimek_insects/Hymenoptera/Apoanagyrus_lopezi/

Figure 17 *Anagyrus lopezi* (De Santis, 1964), (Hymenoptera: Tetracneminae)

Source: https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/phenacoccus-manihoti

Figure 18 *Phenacoccus manihoti* (Matile-Ferrero, 1997) (Homoptera: Pseudococcidae)

Source:http://www.juntadeandalucia.es/agriculturaypesca/visorraif/Ayudas/Olivo/0_Ayuda%20plagas/Paginas%20Foto/PraisRP_CrisalidaParasitadaAgeniaspis.html

Figure 19 *Ageniapis fuscicollis* (Dalman, 1820) (Encyrtidae)

Encyrtus infelix (Embleton, 1902) and *Encyrtus lacaniorum* Walker 1837 are used against *Saissetia* in greenhouse cultures. Native to South America, *Copidosoma uruguyensis* Été lâché, 1968 was released in 1968 in the tobacco growing regions of Madagascar to fight the leaf moth, *Phthorimaea operculella* (Zeller, 1873) (Lepidoptera: Gelechiidae) (Figures 20, 21, 22 and 23) [11].

https://www.alamy.com/stock-photo-parasitoid-wasp-encyrtus-infelix-commercial-biological-control-parasitoid-54721562.html

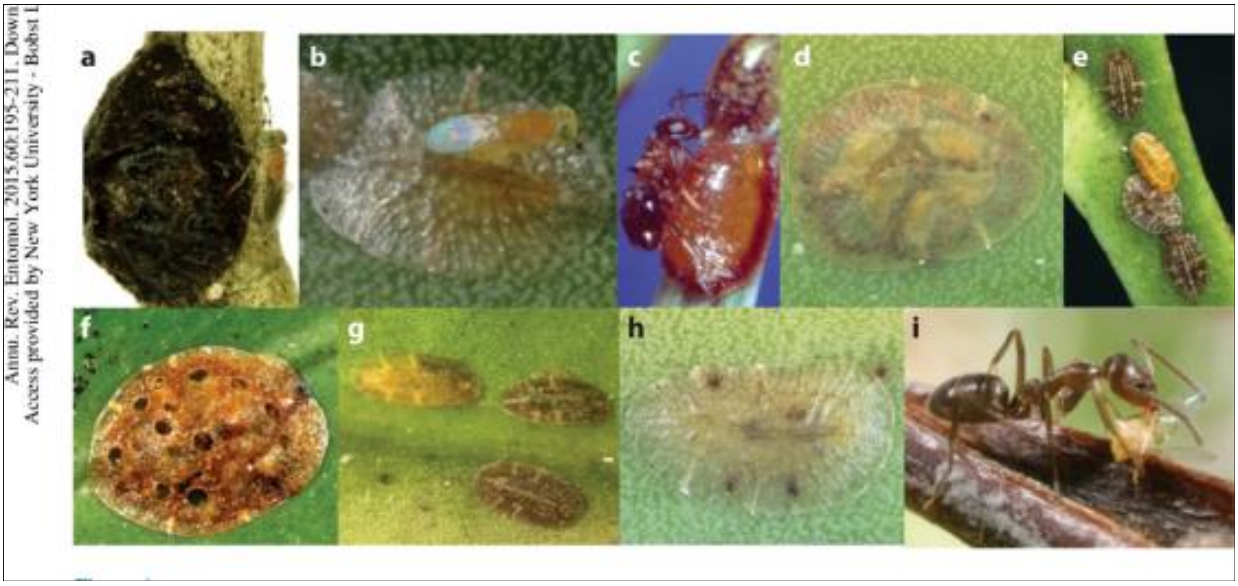
Figure 20 *Encyrtus infelix* (Embleton, 1902)

Source: https://bugguide.net/node/view/517238

Figure 21 *Encyrtus lacaniorum* Walker 1837

Source: Photos Courtesy of CIP

Figure 22 *Phthorimaea operculella* (Zeller, 1873) (Lepidoptera: Gelechiidae). The developmental stages of potato tuber moth, *P. operculella*: (A) egg, (B) larva, (C) pupa, and (D) adults: Female (left) and male (right)



Source: https://www.annualreviews.org/doi/pdf/10.1146/annurev-ento-010814-021053

Figure 23 Coccidae, host utilization, host range, encapsulation, host feeding, and ants

3.2. Study 2

Among the wasps of the family Encyrtidae, parasitoids of eggs and immature stages can be found. and adult insect pests. Soybean in Mato Grosso do Sul has records of these two situations, where *Ooencyrtus* sp. was found parasitizing eggs and adults *Hexacladia smithii* Ashmead, 1891 (Hymenoptera: Encyrtidae) of the stink bug *Euschistus heros* (Fabricius, 1798) (Heteroptera: Pentatomidae), and the latter parasitoid was also found parasitizing the physic stink bug in another region of Brazil, but it can also be found in the state of Mato Grosso do Sul (Figures 24, 25 and 26) [12].

Source: https://www.biodiversidadvirtual.org/insectarium/Ooencyrtus-sp.-3-img859809.html

Figure 24 *Ooencyrtus* sp. (Hymenoptera: Encyrtidae)

Despite the advantage that egg parasitoids have, it is important to point out that the entire complex of natural enemies present in a given culture are important to maintain the population of insect pests below the damage level. However, these natural enemies have their performance affected by a series of chemical products such as insecticides, fungicides and herbicides. In this way the use of selective products, when it is necessary to be applied in the culture is of extreme importance for the conservation of these beneficial agents, acting naturally, or even so that they can be collected, created in laboratory and released in the planting areas.

Source: https://www.researchgate.net/figure/Adulto-de-Hexacladia-smithii-parasitoide-do-percevejo-marrom-Euschistus-heros_fig1_262541615

Figure 25 *Hexacladia smithii* Ashmead, 1891 (Hymenoptera: Encyrtidae)

The association between control methods may reduce the number of chemical insecticide applications crops, providing a reduction in production cost and environmental improvement [12].

Source: http://www.infobibos.com.br/Artigos/2009_3/AmigoOculto/index.htm

Figure 26 *Hexacladia smithii* Ashmead, 1891 (Hymenoptera: Encyrtidae) parasitizing eggs of *Euschistus heros* (Fabricius, 1798) parasitizing (Heteroptera: Pentatomidae)

3.3. Study 3

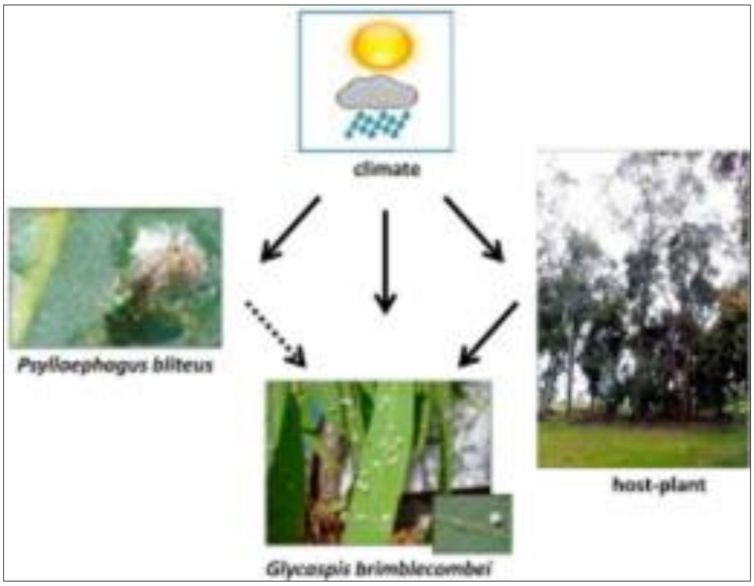
The study aimed to evaluate the pest infestation and parasitism in three species of eucalyptus, therefore, a total of 100 leaves of *Eucalyptus grandis* W. Hill ex Maiden (Myrtaceae) , *Eucalyptus tereticornis* Smith (Myrtaceae) and *Eucalyptus camaldulensis* Dehnh (Myrtaceae) were collected, making a total of 300 leaves, placed in Petri dishes with constantly moistened filter paper, kept in the Entomology Laboratory of the Regional Community University of Chapecó (25±3ºC, RH of 70±10% and photophase of 14h) until the emergence of adults [13,14,15].

A total of 701 shells were collected, being 42.5% in *E. tereticornis*, 34.2% and 23.2% in *E. grandis*. The number of shells obtained in *E. grandis* differed statistically from the others, with an average of 1.6 shells/leaf of the total shells collected, *E. tereticornis* presented an average of 2.9 shells/leaf and *E. camaldulensis* with 2. 4 shells/sheet. The percentage of parasitism observed in *E. grandis* was 49.6%, in *E. camaldulensis* of 48.3% and in *E. tereticornis* of 47.3%. This constitutes the first record of parasitism from *Glycaspis brimblecombei* (Moore, 1964) (Hemiptera: Psyllidae) by *Psyllaephagus bliteus* Riek, 1962 (Hymenoptera: Encyrtidae) to the state from Santa Catarina. Examples of this species are deposited in the Museum's insect collection Zoobotanist at Unochapecó (Figures 27, 28, 29, 30A and 30B) [13,14,15].

Source: https://www.researchgate.net/figure/Glycaspis-brimblecombei-a-damage-on-E-camaldulensis-leaves-b-adult-ceggs-and-lerps_fig1_269406744

Figure 27 *Glycaspis brimblecombei* (Moore, 1964) (Hemiptera: Psyllidae): a-damage on *Eucalyptus camaldulensis* Dehnh (Myrtaceae) leaves, b-adult, ceggs and lerps, d-nymph and lerp

This parasitoid has a biological cycle of approximately 21 to 35 days, in Mexican conditions depending on the time of year, being able to parasitize on average 17 nymphs of the shell psyllid. The parasitoid pierces the shells to oviposit inside the pest nymph. the egg of parasitoid is observed in 3rd and 4th instar nymphs of the psyllid. The larval stage of the parasitoid consumes the pest and the parasitized psyllid nymph fully called "mummy". The parasitoid pupa is found in the 5th instar nymphs [13,14,15].

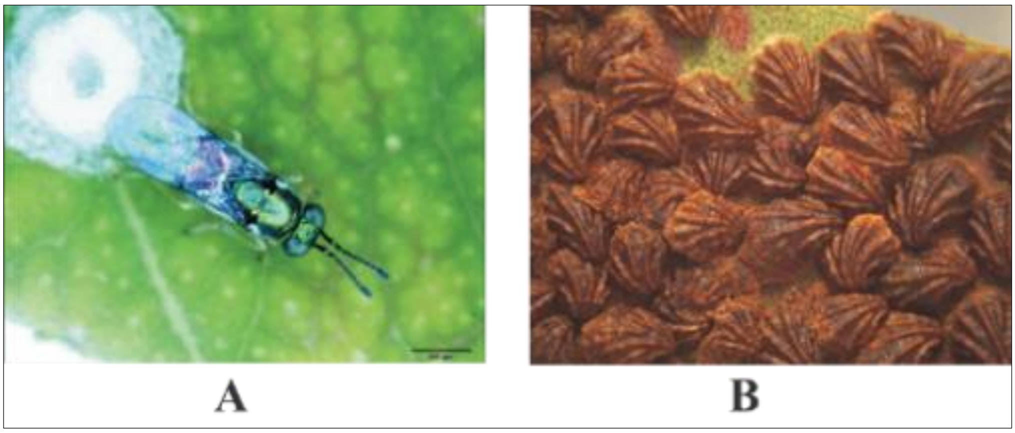


Source: https://www.sciencedirect.com/science/article/abs/pii/S1049964416300536

Figure 28 *Psyllaephagus bliteus* Riek, 1962 (Hymenoptera: Encyrtidae) life cycle

Source: http://www.waspweb.org/chalcidoidea/Encyrtidae/Encyrtinae/Psyllaephagus/Psyllaephagus_bliteus.htm

Figure 29 Dorsal and (b) ventral views of *Psyllaephagus bliteus* Riek, 1962 (Hymenoptera: Encyrtidae) pupae, which are completely enveloped by the black pupal sheath. (c) A mummified psyllid with the parasitoid exit hole and visible remains of the pupal sheath inside. (d) A dissected mummified psyllid showing the discarded black pupal sheath, typically found in two sections with the section formerly covering the head and antennae at the psyllid's posterior end



Source: http://www.waspweb.org/chalcidoidea/Encyrtidae/Encyrtinae/Psyllaephagus/Psyllaephagus_bliteus.htm

Figure 30A *Psyllaephagus bliteus* Riek, 1962 (Hymenoptera: Encyrtidae) ovipositing into a *Glycaspis brimblecombei* (Moore, 1964) (Hemiptera: Psyllidae) (Red Gum lerp psyllid), through the lerp. Figure 30B *Glycaspis brimblecombei* Riek, 1962 (Hymenoptera: Encyrtidae) is a sap-sucking psyllid. The nymphs build conical structures called lerps (image above) from a sugary wax secretion exuded during feeding

3.4. Study 5

In Roraima, citriculture is in expansion phase due mainly to the potential market with the state of Amazonas and neighboring countries, as well as the edaphoclimatic conditions favorable to its development. The occurrence of various pests, with highlighting the citrus leaf miner larva *Phyllocnistis citrella* Stainton, 1856 (Lepidoptera; Gracillariidae), contributes significantly to the reduction production of citrus orchards in the state (Figures 31, 32, 33A and 33B) [16, 17, 18, 19].

Source: https://www.shutterstock.com/pt/search/phyllocnistis

Figure 31 Larvae, pupae and adul of *Phyllocnistis citrella* Stainton, 1856 (Lepidoptera; Gracillariidae)

Source: Photograph by Jeff Lotz, FDACS-DPI

Figure 32 Citrus leaf containing a single leafminer mine, showing the damage that can be done by citrus leafminer, Stainton, 1856 (Lepidoptera; Gracillariidae), feeding

Source: https://content.ces.ncsu.edu/citrus-leafminer

Figure 33A Larva of *Phyllocnistis citrella* Stainton, 1856 (Lepidoptera; Gracillariidae). Figure 33B Eggs of *Phyllocnistis citrella* Stainton, 1856 (Lepidoptera; Gracillariidae)

The citrus leaf miner larva occurs across the state, in the ecosystems of forest, savannah and altitude, presenting infestations around 60% of the leaves. The damage caused by the leaf miner citrus leaf to plants depend on the level of pest infestation, which may impair photosynthesis, cause a fall premature leaf and prevent the development of shoots. As the use of insecticides has not been successful the desired effect, due to the insect larva under the leaf epidermis, the biological control emerges as a viable alternative control (Figure 34) [16, 17, 18, 19].

Source: https://www.ipmimages.org/browse/detail.cfm?imgnum=5190060

Figure 34 Adult of *Phyllocnistis citrella* Stainton, 1856 (Lepidoptera; Gracillariidae)

P. citrella has a large number of natural enemies, the most important belonging to the order Hymenoptera. In Roraima they have already been observed the following parasitoids natives carrying out the biological control of the citrus leaf miner larva: *Galeopsomyia* sp. (Family Eulophidae), *Horismenus* sp. (Family Eulophidae) and *Elasmus* sp. (Family Elasmidae); *Cirrospilus* sp. (Family Eulophidae). In addition to these natives, in 2005, it was introduced the parasitoid *Ageniaspis citricola* Logvinovskaya, 1983 (Family: Encyrtidae), which have also contributed to the control of citrus leaf miner larva in the state (Figures 35A and 35B) [16, 17, 18, 19].

Source: Photograph by M. Hoy, University of Florida; and R. Nguyen, Division of Plant Industry

Figure 35A Pupae and adults of *Ageniaspis citricola* Logvinovskaya, 1983 (Family: Encyrtidae). Figure 35B Adult of *Ageniaspis citricola* Logvinovskaya, 1983 (Family: Encyrtidae)

The citrus leaf miner larva, well like their parasitoids, develop very well at temperatures close to 25 ^{0}C. These temperatures are conducive for releases and establishments of leafminer parasitoids. On the biology of *P. citrella* (Figure 36).

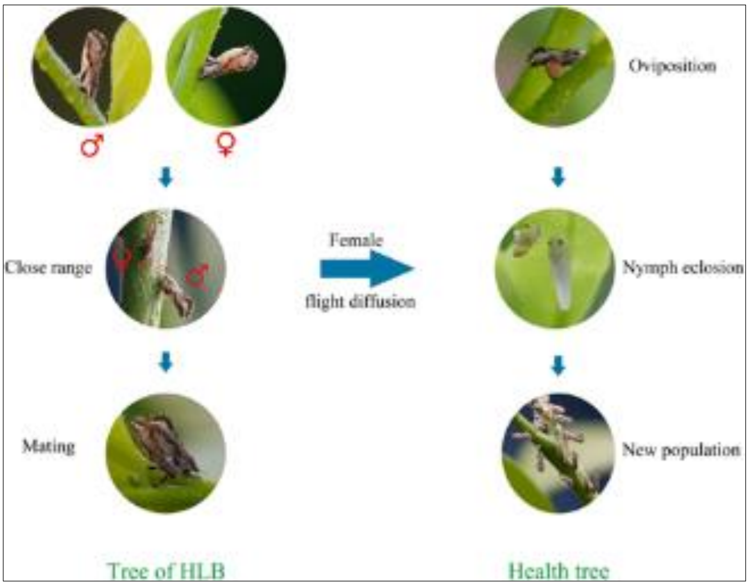
Source: Photograph by M. Hoy, University of Florida; and R. Nguyen, Division of Plant Industry

Figure 36 Pupal cell in leaf with two to four *Ageniaspis citricola* Logvinovskaya, 1983 pupae

In different temperatures, showed that in temperatures between 25 and 28 ºC the viability of the egg, larva and pupa stages are greater than 95% [16,17,18,19].

3.5. Study 6

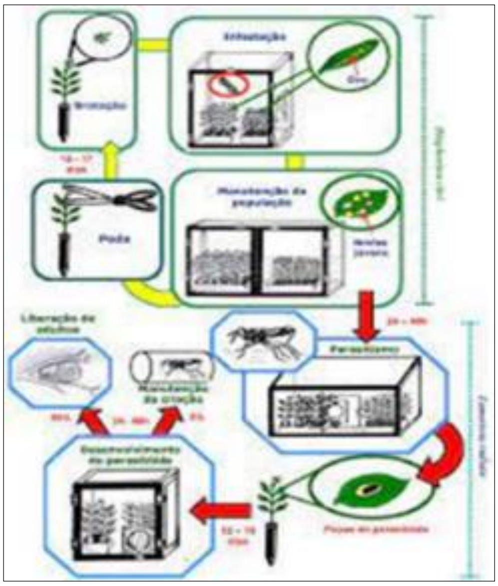
The Asian citrus psyllid *Diaphorina citri* Kuwayama, 1908 (Hemiptera: Liviidae), has been referred to in Brazil since 1942. However, the occurrence of bacteria in the genus *Candidatus* and *Liberibacter* (Rhizobiaceae), associated with the huanglongbing (HLB, ex-greening), was only found, in Brazil, in 2004, with the observation of plants with typical symptoms of this disease in the state of São Paulo. This is, therefore, a peculiar case, since most of the time, as in Florida (USA), few years after the registration of this vector insect, which occurred in 1998, the dissemination of HLB was observed (Figure 37).



Source: https://link.springer.com/article/10.1007/s41348-019-00296-8

Figure 37 Cycle of life *Diaphorina citri* Kuwayama, 1908 (Hemiptera: Liviidae)

The discovery of the new species *Candidatus*. *Liberibacter americanus* (Lam) in Brazil is evidence of that the pathogen may have been introduced via other Rutaceae, since this bacterial species does not had been registered in citrus until then in other regions where the disease is endemic. Although it causes direct damage to citrus, *D. citri* has become the main pest of culture for its ability to transmit the bacteria associated with the HLB the citrus disease huanglongbing (HLB, or greening) was detected in Brazil in 2004 (Figure 38).



Source: https://citrusrt.ccsm.br/article/10.5935/2236-3122.20100004/pdf/citrusrt-31-1-37.pdf

Figure 38 Production scheme of *Tamarixia radiata* (Waterston, 1920) (Hymenoptera: Eulophidae)

The already established Asian citrus psyllid, *Diaphorina citri* Kuwayama, 1908 (Hemiptera: Psyllidae) became an important pest of citrus after the emergence of HLB due to its ability to transmit bacterial species of the genus *Candidatus Liberibacter* spp., which is associated with HLB, Ca. *Liberibacter americanus*, *Ca*. L. asiaticus and Ca. *L. africanus*. Currently, about 5% of plants citrus plants in the state of São Paulo meet with HLB symptoms.

3.5.1. What is greening?

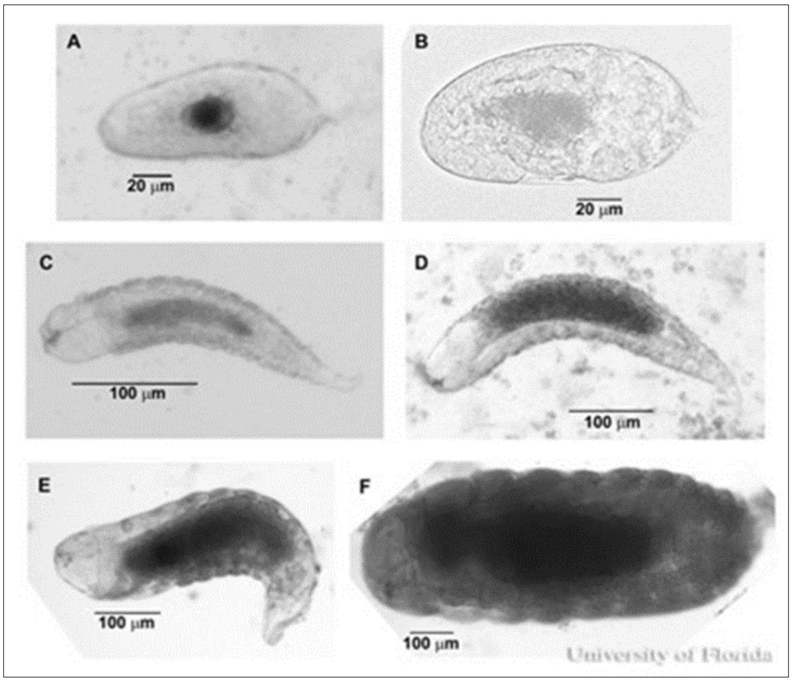
The most destructive citrus disease in Brazil and the greatest threat to the citrus industry worldwide Greening, also known as huanglongbing and HLB, attacks all types of citrus and there is no cure for diseased plants. Affected young trees fail to produce and mature trees in production suffer a large premature fruit drop and wither over time. The bacterium *Candidatus Liberibacter asiaticus* is currently the main cause of the disease in Brazil, present in more than 99% of diseased plants.

Early on, when greening was detected in the country, the bacterium *Candidatus Liberibacter americanus* was the main one, but it has lost importance over time, affecting less than 1% of diseased plants today. The causes of its reduction are the lower transmission rates and greater sensitivity to high temperatures.

The greening bacteria are transmitted by the psyllid *D. citri*, an insect with a grayish white color and dark spots on the wings, with a length of 2 to 3 mm, and very frequent in orchards at the time of plant sprouting. Controlling greening requires planting healthy seedlings, eliminating diseased plants and controlling the psyllid (Figures 39, 40 and 41).

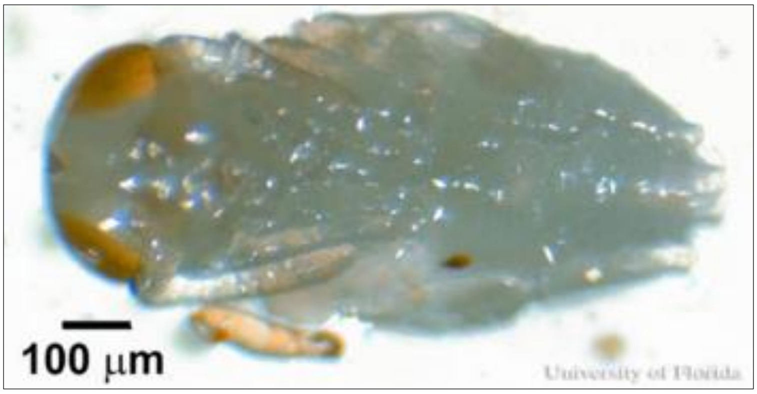
Source: Photograph by Eric Rohrig, University of Florida

Figure 39 Adult female *Diaphorencyrtus aligarhensis* (Shafee, Alam and Agarwal, 1975), a parasitoid of the Asian citrus psyllid, *Diaphorina citri* (Kuwayama, 1908)



Source: Photograph by Eric Rohrig, University of Florida

Figure 40 Immature life stages of *Diaphorencyrtus aligarhensis* (Shafee, Alam and Agarwal, 1975), a parasitoid of the Asian citrus psyllid, *Diaphorina citri* Kuwayama, 1908 (Hemiptera: Liviidae). Eggs shown 12 hours (A) and 24 hours (B) after oviposition. First (C), second (D), third (E) instar larvae, and a fourth instar larva (F) shown shortening by constriction upon entering the prepupal stage



Source: Photograph by Eric Rohrig, University of Florida

Figure 41 Pupating *Diaphorencyrtus aligarhensis* (Shafee, Alam and Agarwal, 1975), a parasitoid of the Asian citrus psyllid, *Diaphorina citri* Kuwayama, 1908 (Hemiptera: Liviidae). The pupa is beginning melanization

Among the parasitoids of the species occurring in the Brazil, we opted for the ectoparasitoid *Tamarixia radiata* (Waterston, 1922) (Hymenoptera: Eulophidae) in relation to t the endoparasitoid *Diaphorencyrtus aligarhensis* (Shafee, Alam & Agarwal, 1975) (Hymenoptera: Encyrtidae), for the success records of the first species in the Reunion Islands in 1978 and Guadeloupe in 1999, with releases of 4,600 and 1,000 adults, in both locations, respectively [20, 21, 22, 23, 24 and 25].

4. Conclusion

The Encyrtidae are entomophagous insects: two out of three Encyrtidae are solitary endoparasitoids of hemipterans, mainly mealybugs of the genus *Leucanium*. The remainder parasitizes eggs, larvae or pupae of lepidopterans, leaf beetles, insects, mosquitoes and ticks. Copidosomatini are all Lepidoptera parasites.

Compliance with ethical standards

Disclosure of conflict of interest

The author has no conflict of interest.

References

[1] Guerrieri E, Noyes JS. Revision of European species of genus *Metaphycus* Mercet (Hymenoptera: Chalcidoidea: Encyrtidae), parasitoids of scale insects. Systematic Entomology. 2000; 25: 147-222.

[2] Rameshkumar A, Poorani J, Joshi M. New Distribution and Host Records of Encyrtidae (Hymenoptera: Chalcidoidea) from India Including First Reports of *Acerophagus Orientalis* (Ferriere) and *Cryptanusia Albiclava* Girault. Transactions of the American Entomological Society. 2016; 142(1): 41–53.

[3] Trjapitzin VA. A review of encyrtid wasps (Hymenoptera, Chalcidoidea, Encyrtidae) of Macaronesia, Entomological. Review. 2008; 88(2): 218–232.

[4] Noyes JS. Encyrtidae of Costa Rica (Hymenoptera: Chalcidoidea), 1. The subfamily Tetracneminae, parasitoids of mealybugs (Homoptera: Pseudococcidae). Memoirs of the American Entomological Institute. 2000; 62: 1-355.

[5] Ashmead WH. On the genera of the chalcid-flies belonging to the sub-family Encyrtinae. Proceedings of the United States National Museum. 1900; 22: 323-412.

[6] Noyes JS. Collecting and preserving chalcid wasps (Hymenoptera: Chalcidoidea). Journal of Natural History. 1982; 16(3): 315-334.

[7] Noyes JS, Fallahzadeh M. *Psyllaephagus zdeneki* sp. nov. (Hymenoptera: Encyrtidae) from Iran, a parasitoid of *Euphyllura pakistanica* (Hemiptera: Psyllidae). Acta Zoologicae Bohemoslovenica. 2005; 69: 203-208.

[8] Prinsloo GL. On the encyrtid parasites (Hymenoptera: Chalcidoidea) associated with psyllids (Hemiptera: Psylloidea) in southern Africa. Journal of the Entomological Society of Southern Africa. 1981; 44: 199-244.

[9] Simutnik SA. The first record of Encyrtidae (Hymenoptera, Chalcidoidea) from the Sakhalin amber. Paleontological Journal. 2014; 48(6): 621-623.

[10] Marchiori CH. Biology and feeding behavior of ceratopogonid adult (Diptera: Ceratopogonidae). International Journal of Frontiers in Science and Technology Research. 2021; 1(2): 7–24.

[11] Singh S. Two new species of *Psyllaephagus* Ashmead (Hymenoptera: Chalcidoidea: Encyrtidae) attacking *Mycopsylla* sp. (Homoptera: Psyllidae) infesting Ficus religiosa in Mizoram, India. Oriental Insects. 1996; 30(1): 155-166.

[12] Hoffer A. Descriptions of new species of the family Encyrtidae from Czechoslovakia (Hym, Chalcidoidea) II. Journal of the Entomological Society of Cechoslovenica 1963; 60(1/2): 132-132.

[13] Garcia FRM, Savaris M, Pereira DVM. Primeiro registro do parasitoide *Psyllaephagus bliteus* Riek (Hymenoptera, Encyrtidae) no Estado de Santa Catarina, Brasil. Biodiversidade Pampeana. 2011; 9(1): 61-63.

[14] Bush SJ, Slippers B, Neser S, Harney M, Dittrich-Schroder G, Hurley BP. Six recently recorded Australian insects associated with *Eucalyptus* in South Africa. African Entomology. 2016; 24: 539 –544.

[15] Daane KM, Sime KR, Dahlsten DL, Andrews JW Jr., Zuparko RL. The biology of *Psyllaephagus bliteus* Riek (Hymenoptera: Encyrtidae), a parasitoid of the red gum lerp psyllid (Hemiptera: Psylloidea). Biological Control. 2005; 32: 228-235.

[16] Yang CK, Li FS. Notes on the genus *Macrohomotoma* and descriptions of six new species from China (Homoptera: Psyllidae). Acta Agricultural University of Pekin. 1984; 4: 369-380.

[17] Tan YG, Zhao JZ. One new species and one newly recorded species of the genus *Psyllaephagus* Ashmead from China (Hymenoptera: Encyrtidae. Journal of Hubei University (Natural Science). 1999; 21(2): 174-176. [18] Chow CY. The common blue bottle fly *Chrysomya megacephala* as a carrier of pathogenic bacteria in Beijing. Chinese China Medicine. 1940; 57:145-153.

[18] Chow CY. The common blue bottle fly *Chrysomya megacephala* as a carrier of pathogenic bacteria in Beijing. Chinese China Medicine. 1940; 57:145-153.

[19] Noyes JS. A review of genera of Neotropical Encyrtidae (Hymenoptera: Chalcidoidea). Entomology Services. 1980; 411-253.

[20] Parra JRP, Lopes JRS, Torres MLG, Nava DE, Paiva PEB. Bioecologia do vetor *Diaphorina citri* e transmissão de bactérias associadas ao huanglongbing. Citrus Research & Technology. 2010; 31(1): 37-51.

[21] Bové JM. Huanglongbing: a destructive, newly emerging, century-old disease of citrus. Journal of Plant Pathology. 2006; 88: 7-37.

[22] Silveira GAS, Madeira PNG, Azeredo-Espin AML. Levantamento de microhimenópteros parasitóides de dípteros de importância médico-veterinária no Brasil. Memórias do Oswaldo Cruz. 1989; 84: 505-510.

[23] Coletta-Filho HD, Targon MLPN, Takita MA, De Negri JD, Pompeu JrJ, Machado MA, Do Amaral AM, Muller GW. First report of the causal agent of huanglongbing (*Candidatus Liberibacter asiaticus*) in Brazil. Plant Disease. 2004; 88: 1382.

[24] Aubert B. *Trioza erytreae* del Guercio and *Diaphorina citri* Kuwayama (Homoptera: Psylloidea), the two vectors of citrus greening disease: Biological aspects and possible control strategies. Fruits. 1987; 42: 149-162.

[25] Viggiani G, Mazzone P. Preliminary news *sulla* introduzione in Italia di *Metaphycus* aff. *stanleyi* Comp. and *Diversinervus elegans* Silva. (Hym, Encyrtidae), parasites of *Saissetia oleae* (Oliv.), Bulletin of the Laboratory of Agrarian Entomology Filippo. 1977; 34: 217–222.