https://doi.org/10.53964/jmab.2023006

https://www.innovationforever.com

Journal of
Modern Agriculture and Biotechnology

ISSN 2788-810X (Online)

Open Access

Review

The Potential of the Figitidae Family as Natural Insect Regulators Pests (Insecta: Hymenoptera)

Carlos Henrique Marchiori[1*]

[1]Department of Biological Science, Instituto Federal Goiano, Goias, Brazil

[*]**Correspondence to: Carlos Henrique Marchiori, PhD, Professor,** Department of Biological Science, Instituto Federal Goiano, Rua T-65 No. 1050, Goiânia, Goiás 74230120, Brazil; E-mail: chmarchiori@yahoo.com.br

Received: August 2, 2022 **Revised:** September 5, 2022 **Accepted:** September 30, 2022 **Published:** February 20, 2023

Abstract

Eucoilinae, belonging to the Figitidae family, are the most abundant and diverse parasites of this family, which potentially be used for biological control in different localities and cultures and are widely distributed throughout Latin America, with a high efficiency in natural conditions. However, the diversity and biology of these individuals remains poorly understood and they are examined on a global scale. The diversity and biology of these individuals still are little known, however, reviews in global scale about them. The objective of this work is to investigate the biology, ecology, habitat, geographic distribution, taxonomy, life cycle, phenology, biological control, and work carried out on the Figitidae family (Insecta: Hymenoptera). The revision research was carried out based on studies related to the quantitative and conceptual aspects of Figitidae. A bibliographic search was carried out containing national and international articles from 1986 to 2022. The mini-review was carried out in Goiânia, Goiás, from September to October 2021, using digital platforms such as: Abstract, Scielo, ResearchGate, Academia.edu, Frontiers, Publons, Wide Science, Springer, RefSeek, Microsoft Academic Science Research.com, CAPES Periodicals, Google Academic, Bioline International, Scopus, Web of Science, Portal of Scientific Journals in Health Sciences and the internet. The results obtained from the present study indicate the need for more studies on Figitidae fauna to contribute to refine the related knowledge.

Keywords: cynipoid, parasitoid primary, parasitoids, hyperparasitoids

Citation: Marchiori CH. The Potential of the Figitidae Family as Natural Insect Regulators Pests (Insecta: Hymenoptera). *J Mod Agric Biotechnol*, 2023; 2(1): 6. DOI: 10.53964/jmab.2023006.

1 INTRODUCTION

The family has recently been phylogenetically redefined to include the previously recognized Charipidae and Eucoilidae, and is now assigned subfamily status in the broader definition of Figitidae. Figitids are all relatively small species (1.5-3mm) that are characterized by a weak point in the 9th metasomal tergum of females that allows some flexibility in the ovipositor, and the Rs + M vein in the fore wing issuing close to Cu. Figitidae is the largest Cynipoidea family in Australia and there are also a significant number of undescribed taxa[1-3].

Charipinae, which lack mesosomal sculpturing, are hyperparasitoids of aphid or psylloid (Hemiptera) primary

https://doi.org/10.53964/jmab.2023006

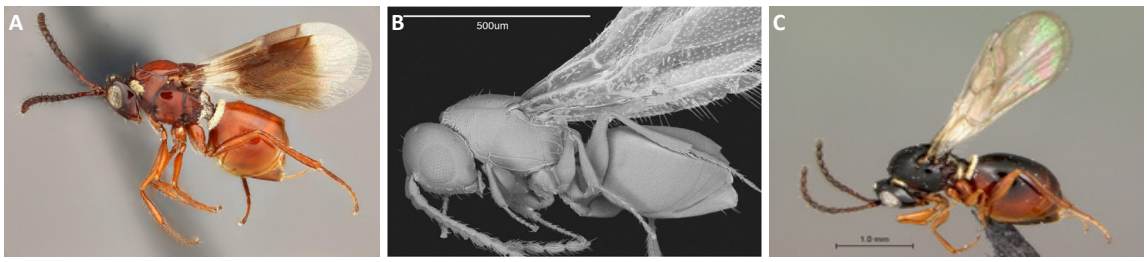

Figure 1. Specimens of Figitidae family (A, B and C). Sources: http://www.waspweb.org/cynipoidea/figitidae/eucoilinae/index.htm, http://www.waspweb.org/cynipoidea/figitidae/eucoilinae/Garudella/Garudella_afrotropica.htm and http://www.waspweb.org/cynipoidea/figitidae/eucoilinae/Trichoplasta/index.htm

hosts; Figitinae are endoparasitoids of Diptera (flies) and are often associated with dung flies; while Anacharitinae parasitize green and brown lacewings (Neuroptera). The largest subfamily is the Eucoilinae which are easily identified by the presence of a raised, medially depressed plate or 'cup' on the scutellum, and are endoparasitic on various Cyclorrhapha Diptera[1-3].

The subfamily Eucoilinae are the most abundant and diverse, which belong to the group of figitids are the most abundant and diverse parasitoids of this family, being used potentially in biological control in different places and cultures, are widely distributed throughout Latin America, with high efficiency under natural conditions. The diversity and biology of these individuals remains poorly understood, yet they are being examined globally (Figure 1A and B)[1-3].

One of the most important families of this group, acting as agents of natural biological control, allows the development of the largest number of fruits. Together with Opiinae (Hymenoptera: Braconidae), they serve as the most important natural enemies of fruit flies. Individuals belonging to this subfamily are demonstrated below (Figure 1C)[4-6].

1.1 Description

The Figitidae, despite being distributed all over the world, has few acquaintances. The larvae of endopterygote insects, ranging from 0.75mm to 5.00mm, are classified. The vast majority of species have a right black color, however, there are some species that are dark brown in color (Figure 2).

Females present, in most of their cases, an elongated form, with segments gradually expanding to an apex of 13 flagella, and some rare species may present only 12 flagella (Figures 3-9)[7-9].

1.2 Biology

Species of the Figitidae (Eucoilinae) family are symbiotic endoparasitoids of the larvae of the Cyclorrhapha Diptera, which are parasites. As a microscopic hymenopteran, they develop inside their hosts, allowing them to grow and develop (Figure 10)[10-12].

They feed on larvae of Diptera or Hemerobiidae and Chrysopidae (Neuroptera) or Syrphidae (Diptera); of cynipoid or chalcidoid gall wasps; or from Braconidae or Chalcidoidea that parasitize Hemiptera some species that are associated exclusively with families whose larvae are frugivorous such as Tephritidae, Lonchaeidae, Drosophilidae, Neriidae, Ottidae Muscidae, Sepsidae, Sarcophagidae, Sphaeroceridae, Agromyzidae, Drosophilidae, Chloropodiae, Phoridae, Neriidae and Anthomyiidae. Parasitoids of cynipoid or chalcidoid gall inducers, or hyperparasitoids of Hemiptera through Braconidae or Chalcidoidea (Figures 11 and 12)[10-12].

1.3 Biocontrol

The Eucoilinae, together with the Opiinae, are considered the most important parasitoid of larvae of frugivorous dipterans. Figitids (Eucoilinae) have been collected in almost all *Drosophila* surveys, however in small numbers compared to braconids. Due to their relationship with tephritids, these parasites play an important role as natural enemies of fruit flies, however, the lack of knowledge challenges the use of these parasites in management programs[13-15].

1.4 Taxonomy

Figitidae is a family of parasitoid wasps. 1,400 species have been described in more than 130 genera but many remain to be described. For example, the largest subfamily, Eucoilinae (previously considered a separate family, Eucoilidae or placed within Cynipidae) has more than 1,000 described species but this is thought to be only a fraction of the total diversity[16-19].

Subfamilies: Twelve subfamilies are considered (2011): Aspicerinae, Charipinae, Emargininae, Euceroptrinae, Eucoilinae, Figitinae, Mikeiinae, Parnipinae, Plectocynipinae, Pycnostigminae and Thrasorinae (Figures 13-15)[20-22].

1.5 Objective

The aim of this manuscript is to report the potential

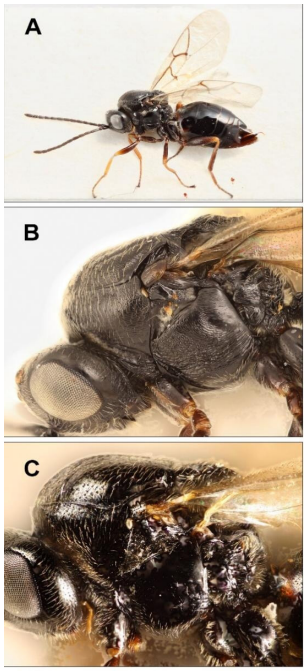

Figure 2. ***Amphithectus austriacus*** **(Tavares, 1928).** A: Female habitus; B: Mesosoma from a specimen displaying dense, coriaceous microsculpture (male specimen, diffused light); C: Mesosoma from a shiny specimen without dense microsculpture (female specimen reared together with the coriaceous male, light not diffused, in order to facilitate comparison with 2B). Source: https://www.semanticscholar.org/paper/The-identity-of-fi-gitid-parasitoids-(-Hymenoptera-Forshage/e4ead547e68170ca406c48a520e769771a807d1f/figure/2

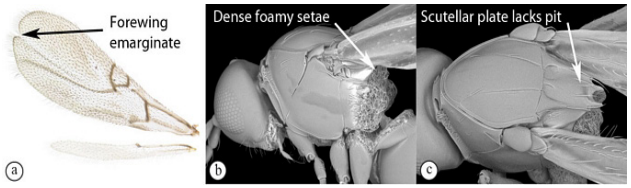

Figure 3. Emarginainae. a: Apical margin of forewing distinctly emarginated; b: Dense 'foamy' setae present on propodeum and anterior of metasoma; c: Scutellar plate occasionally present, but lacking central pit. Source: http://www.waspweb.org/Cynipoidea/Keys/Dichotomus_keys/Figitidae_subfamilies/index.htm

of the family Figitidae as insect regulators (Insecta: Hymenoptera).

2 METHODS

The literature search was carried out containing national and international articles from 1986 and 2022 to retrieve research concerning quantitative, taxonomic, and conceptual aspects. A mini-review was prepared in Goiânia, Goiás, between September and October 2021, by means of the Biological Abstracts, Periodicals CAPES and Scielo (Marchiori 2022)[23].

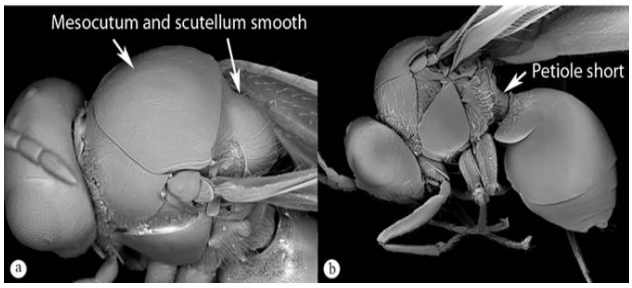

Figure 4. Charipinae. a: Mesoscutum and scutellum completely smooth and rounded, entirely lacking sculpture; b: Petiole very short, at most as long as broad. Source: http://www.waspweb.org/Cynipoidea/Keys/Dichotomus_keys/Figitidae_subfamilies/index.htm

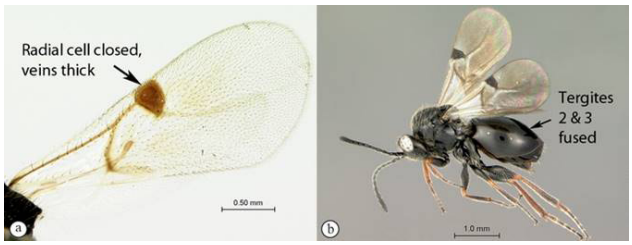

Figure 5. Pycnostigminae. a: Radial cell of forewing strongly reduced, closed, its veins thick and heavy; b: Metasoma with segments 2 and 3 forming a syntergum. Source: http://www.waspweb.org/Cynipoidea/Keys/Dichotomus_keys/Figitidae_subfamilies/index.htm

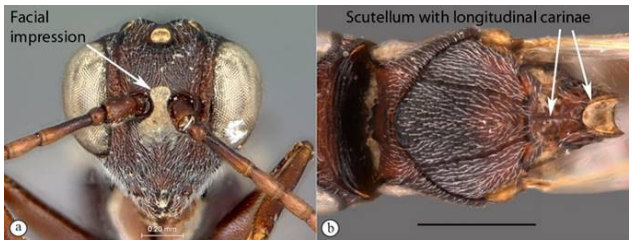

Figure 6. Aspicerinae. a: Facial impression usually present between toruli; b: Tergite 2 of metasoma liguliform; hind tibiae in most genera longitudinally ridged or furrowed on outer margins or posteriorly. Scutellum with one or more longitudinal carinae and subapically with either a spine or foveae. Source: http://www.waspweb.org/Cynipoidea/Keys/Dichotomus_keys/Figitidae_subfamilies/index.htm

3 STUDIES CONDUCTED AND SELECTED

3.1 Study 1

One hundred and sixty six (66) samples from 51 municipalities in the five regions of Brazil. 2025 Eucoilinae were obtained, however, only in 27 municipalities were found parasitoid eucolines of larvae of tephritids.

Six were collected: *Aganaspis nordlanderi* Wharton, 1998, *Aganaspis pelleranoi* (Brèthes, 1924), *Diceratasplis flavipes* (Kieffer, 1909), *Lopheucoila anastrephae* (Rhower, 1919), *Odontosema anastrephae* Borgmeier,

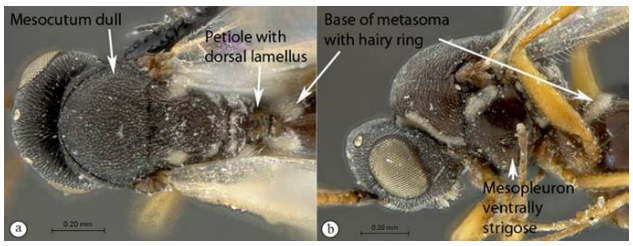

Figure 7. *Melanips* (Aspicerinae). a: Petiole with dorsal lamellus, which partially covers the junction between the petiole and the nucha; b: Mesopleuron dorsally smooth and shiny, ventrally strigose; a and b: Base of metasoma with a complete hairy ring and mesopleuron dorsally smooth and shiny, ventrally strigose. Source: http://www.waspweb.org/Cynipoidea/Keys/Dichotomus_keys/Figitidae_subfamilies/index.htm

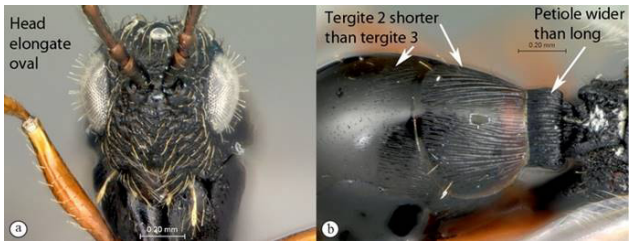

Figure 8. Figitinae. a: Head, in anterior view, elongate oval to round, as wide as, or narrower than mesosoma; b: Tergite 2 of metasoma shorter than third; petiole never as long as wide. Source: http://www.waspweb.org/Cynipoidea/Keys/Dichotomus_keys/Figitidae_subfamilies/index.htm

Figure 9. Anacharitlnae. A: Head, in anterior view, roughly triangular, occasionally wider than mesosoma; B: Tergite 2 of metasoma longer than third; petiole at least as long as wide, generally more than twice as long as wide. Source: http://www.waspweb.org/Cynipoidea/Keys/Dichotomus_keys/Figitidae_subfamilies/index.htm

Figure 10. Parasitoid (Hymenoptera: Figitidae) versus invasive fly (Diptera: Drosophilidae). The wasp may soon parasitize the larva of this devastating multi-fruit pest. Source: http://www.waspweb.org/Cynipoidea/Figitidae/Eucoilinae/Leptopilina/Leptopilina_japonica.htm

Figure 11. Parasitism of the family Figitidae. Source: https://ferrebeekeeper.wordpress.com/tag/parasitoid

Figure 12. The parasitoid wasp injecting eggs into a paralyzed hoverfly larva. Source: https://inaturalist.nz/photos/1119659

1935 and *Trybliographa* sp. These species represented 42.8%, and the others (57.2%) were parasitoids of Drosophilidae or the identification was not possible (Figure 16)[24].

You eucoylines are widely distributed in the Brazil. Some species are being registered for the first time in the following States: Amazonas (*A. pelleranoi, A. nordlanderi* and *O. anastrephae*); Rio de Janeiro (*A. pelleranoi*), São Paulo (*D. flavipes*); Santa Catarina (*O. anastrephae*). These parasitoids were also obtained in the states of Bahia, Mato Grosso do Sul, Paraná and Rio Grande do Sul South, places where they had already been found previously (Figures 17 and 18)[24].

In the South Region, there was a lower diversity of eucoylines, only two species (*A. pelleranoi* and *O. anastrephae*). These species are the most widely distributed, found in practically all regions of Brazil. *Aganaspis nordlanderi* is more restricted to North region, however, some specimens were also obtained in the State of São Paulo. *Diceratataspis flavipes* and *Trybliographa* sp. showed the lowest geographic distribution, occurring in the State from São Paulo. *Lopheucoila anastrephae*

https://doi.org/10.53964/jmab.2023006

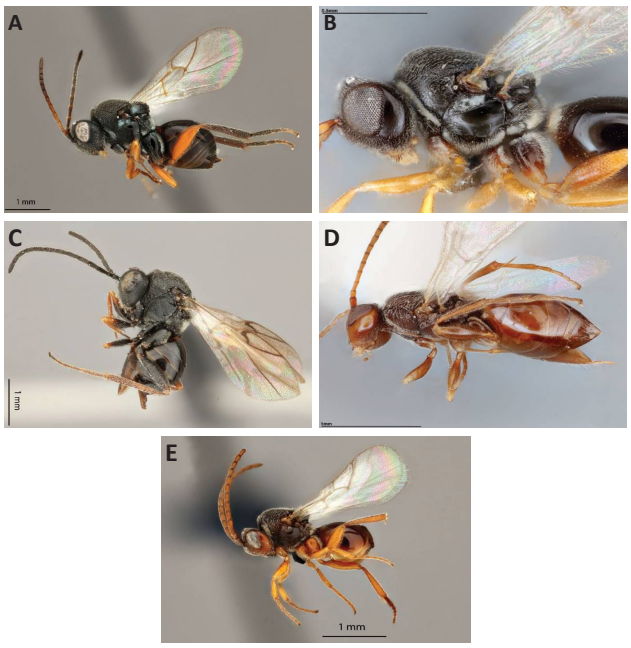

Figure 13. Subfamilies. A: Subfamily euceroptrinae (Holarctic); B: Subfamily Mikeiinae (Australian); C: Subfamily Parnipinae (Palaearctic); D: Subfamily Plectocynipinae (Neotropical); E: Subfamily Thrasorinae (Indo-Australasian, Nearctic, Neotropical). Source: http://www.waspweb.org/cynipoidea/Figitidae/index.htm

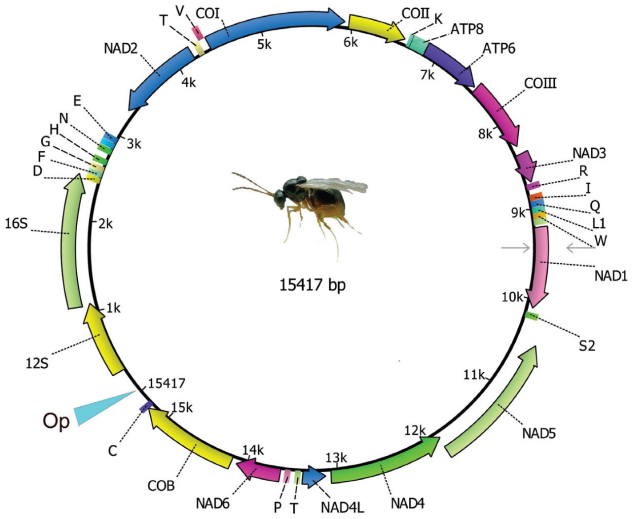

Figure 14. Summary of mitochondrial genome content and organization. ND1-6 and 4L refer to NADH dehydrogenase subunits 1-6 and 4L, COI-III refers to cytochrome c oxidase subunits 1-3, ATP6 and ATP8 refer to ATPase subunits 6 and 8, and Cyt b refers to cytochrome b; rrn refers to ribosomal RNA genes. Letters are the respective tRNAs genes. Op refers the missing region in the assemblage. Arrows indicate gene direction. Source: https://www.scielo.br/j/gmb/a/wKHHwdhHyLHgdxYTFvkdJqk/?format=pdf&lang=en

was obtained in the states of Mato Grosso do Sul and of São Paulo and, like *Trybliographa* sp., seems to be restricted to the Midwest regions and Southeast of Brazil (Figure 19)[24].

Aganaspis pelleranoi was the parasitoid most abundant, representing 30.0% of all the eucoylines associated with the larvae of tephritids (Figure 20)[24].

3.2 Study 2

New record of *Zamischus brasiliensis* Ashmead, 1903 (Hymenoptera: Figitidae) in the Brazilian Amazon (Figure 21A and B).

We observed 63 specimens of Eucoilinae, from the Brazilian Amazon, present in INPA's Invertebrate Collection. Of these, only one specimen of *Zamischus* was found, being identified as *Z. brasiliensis* (Figure 21C).

Material examined: Brazil, Amazonas, Beruri, Estrada do Incra km 03, 03°56'02" S/61°19'03"W/29. The main characteristics for the identification of the genus are: Open marginal cell, smooth mesoscutum with some sparse punctuations, posterior margin of the pronotal plate with two prominent teeth and a furrowed petiole. *Zamischus brasiliensis* differs from the other species of the genus basically by the presence of the character set: long petiole and short gaster; antenna extended towards the apex; scutellar board small with peripheral scores (Figure 21D).

The distribution of this species was known only for Chapada dos Guimarães (Mato Grosso), Santarém (Pará), Nova Teutonia (Santa Catarina) in Brazil and Dos de Mayo (Provincia de Misiones) in Argentina. So, its distribution is expanded to the state of Amazonas. It is also worth noting the importance to study the presence of this genus in other biomes, such as Caatinga, Cerrado, Atlantic Forest, Pampa and Pantanal for a better understanding of group distribution[25].

3.3 Study 3

Thus, the objective was to identify the species of aphids and parasitoids and to analyze the population fluctuation of aphids in the cabbage leaf crop, *Brassica oleracea* L. (Brassicaceae). The kale was cultivated with inter-row and inter-plant spacing. No pesticides were applied at or near the experiment. The collections were initiated when the presence of aphids in the culture was observed. A total of 19 collections were performed[26].

In total, 3223 aphids were collected, 2626 of the species *Brevicoryne brassicae* (Linnaeus, 1758) (Hemiptera: Aphididae), 567 of the species *Lipaphis pseudobrassicae* (Davis, 1914) (Hemiptera: Aphididae) and 30 of the species *Myzus persicae* (Sulzer, 1776) (Hemiptera: Aphididae) (Figure 22).

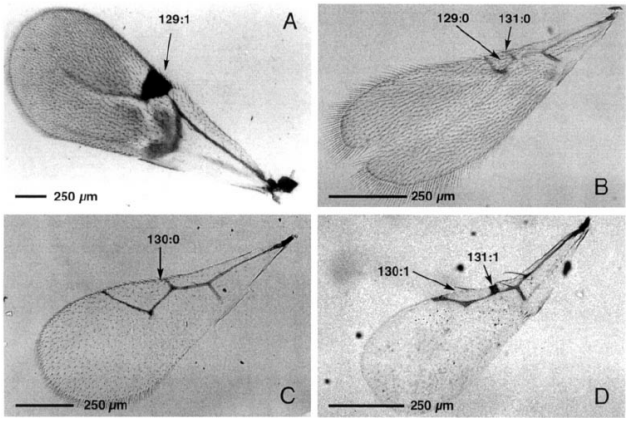

Figure 15. Left forewing of female. A: *Pycnostigmus* sp. (Pycnostigminae); B: *Thoreauella* sp. (Emargininae); C: *Nordlandiella abdominalis* Díaz, 1982 (unplaced); D: *Triplasta* sp. (*Kleidotoma* group). Numbers refer to characters and character states. The placement of taxa follows our suggested division of Eucoilinae into informal groups and not Norlander's original genus groups. Source: https://www.researchgate.net/figure/Left-forewing-of-female-A-Pycnostigmus-sp-Pycnostigminae-B-Thoreauella-sp_fig11_236590909

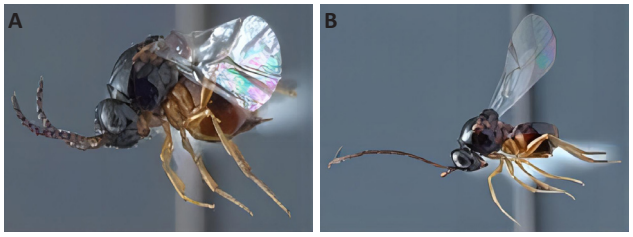

Figure 16. *Aganaspis pelleranoi* (Brèthes, 1924) (A) and *Aganaspis nordlanderi* Wharton, 1998 (B). Source: Photographs © Robert Wharton (Texas A&M University).

Figure 17. *Dicerataspis flavipes* (Kieffer, 1909). Sources: http://www.waspweb.org/Cynipoidea/Figitidae/Eucoilinae/Dicerataspis/Dicerataspis_species.htm

One species of primary parasitoid *Diaeretiella rapae* (McIntosh, 1855) (Hymenoptera: Braconidae) and the hyperparasitoids of genera *Alloxysta* (Figitidae), *Achyneuron* (Pteromalidae) and *Syrphophagus* (Encyrtidae). The percentage of parasitoid emergence was 30.8%. *Diaeretiella* rapae that emerged from a mummy of *L. pseudobrassicae*. Between December 2018 and February 2019, the percentage of emergence was 84.4%, with an average of 57.6%, all emerged from mummies of *B. brassicae*. The average percentage of

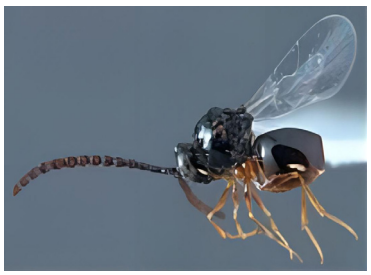

Figure 18. *Lopheucoila anastrephae* (Rhower, 1919). Source: http://www.waspweb.org/Cynipoidea/Figitidae/Eucoilinae/Lopheucoila/Lopheucoila_anastrephae.htm

Figure 19. *Odontosema anastrephae* (Borgmeier, 1935). Source: http://www.waspweb.org/Cynipoidea/Figitidae/Eucoilinae/Odontosema/Odontosema_anastrephae.htm

Figure 20. *Trybliographa* sp. Source: http://www.waspweb.org/cynipoidea/figitidae/eucoilinae/Trybliographa/Trybliographa_species.htm

parasitoidism was 5.3% (Figure 23)[26].

Of the total number of hymenoptera that emerged, 73.8% and 26.2% were secondary (hyperparasitoid) and primary parasitoids, respectively. Of this total of Hymenoptera emerged 47.5% are from the hyperparasitoid of the genus *Alloxysta*. This result evidences the high rate of hyperparasitoidism in populations of aphids that attack leafy cabbage plants (Figure 24)[26].

3.4 Study 4

The objective of this study was to verify the percentage of parasitism and hosts of *Triplasta atrocoxalis* 1865 (Hymenoptera: Figitidae: Eucoilinae) in buffalo and cattle feces in Brazil.

The experiment was carried out in three rural properties in the south of the state of Goiás. January

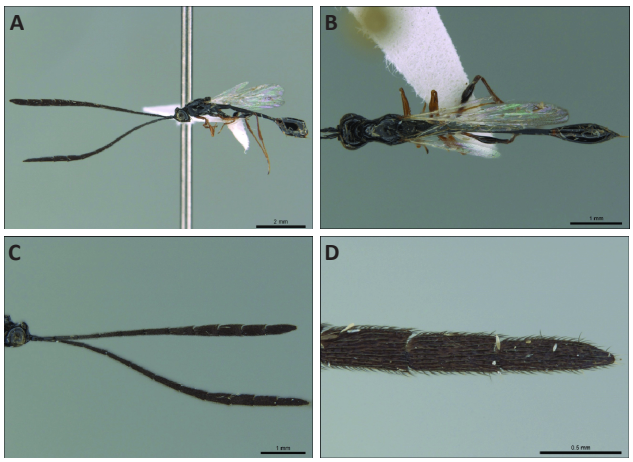

Figure 21. *Zamischus brasiliensis* Ashmead, 1903, female. A: Lateral habit; B: Dorsal habit; C: Antenna widening at apex; D: Lagelomeres 11-13 (detail). Source: https://www.researchgate.net/figure/Figura-2-Zamischus-brasiliensis-Ashmead-1903-fe-mea-habito-dorsal-Figure-2_fig2_335830692

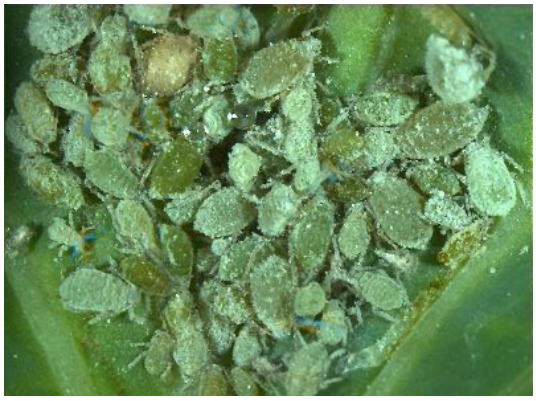

Figure 22. *Brevicoryne brassicae* (Linnaeus, 1758) (Hemiptera: Aphididae). Source:https://www.agrolink.com.br/problemas/pulgao-da-couve_303.html

Figure 23. Hyperparasitoids of genera *Alloxysta* (Figitidae). Source: https://www.researchgate.net/figure/FIGURES-6-9-Habitus-of-Alloxysta-Figitidae-Charipinae-6-A-fuscicornis-7-A_fig4_267511534

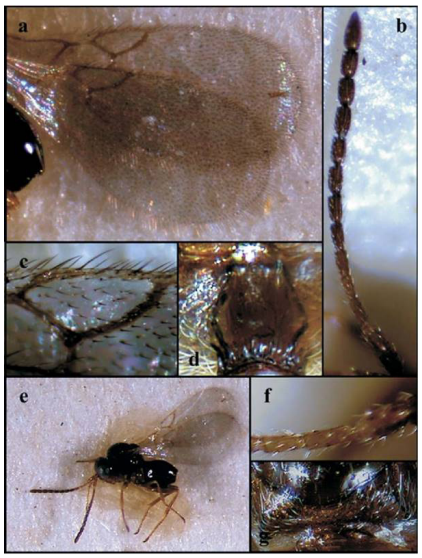

Figure 24. *Alloxysta* sp.1, female. a: Forewing; b: Antenna; c: Radial cell; d: Propodeum; e: Body; f: Detail of antenna; g: Pronotum. Source: http://sea-entomologia.org/PDF/Boletin51/237249BSEA51AlloxystabrevisgroupCynipoideacolor.pdf

1998 to June 2004 and from May 2003 to June 2004, respectively[27].

A total of 6618 Diptera pupae were collected the from which 134 solitary parasitoids of the species *T. atrocoxalis* emerged, showing a 2.0% percentage of parasitism (Table 1). In bovine faeces, the percentage of parasitism was 2.5% and, in buffalo faeces, 0.1%. The host species that showed the highest percentage of parasitism in bovine feces were *Palaeosepsis* spp. (Diptera: Sepsidae) with 6.3%[27].

3.5 Study 5

In southern Brazil, the South American fruit fly, *Anastrepha fraterculus* (Wiedemann, 1830) (Diptera: Tephritidae) is the main pest of temperate fruit trees, and parasitoids are important biological control agents for this pest. This work aimed to survey the parasitoids associated with *A. fraterculus* in native fruits (Figure 25).

Cherry, blackberry, pitanga, araçá-vermelho and guabiroba fruits were evaluated, collected at Epagri/Experimental Station in Caçador, SC, from October/2015 to March/2016 (Figure 26)[28].

Parasitoids emerged only in araçá-vermelho and guabiroba. In araçá-vermelho, *Doryctobracon brasiliensis* (Szépligeti, 1911), *Doryctobracon areolatus* (Szépligeti, 1911) (Braconidae), *Aganaspis nordlanderi* Wharton, 1998 and *Aganaspis pelleranoi* Brèthes, 1924) (Figitidae) were recorded. In guabiroba, only *A. nordlanderi* was recorded. So far, in Brazil, *A. nordlanderi* has been recorded only in Amazonas, Mato Grosso do Sul and São Paulo. Thus, to confirm the species, a specimen of the parasitoid was sent to a taxonomist specializing in Figitidae. This is, therefore,

Table 1. The Percentage of Parasitism of *Triplasta atrocoxalis* (Ashmead, 1865) (Hymenoptera: Figitidae) from Cattle and Buffalo Feces in Brazil

Substrate	Diptera	Pupae Obtained	Parasitized Pupae	%
Bovine feces	*Archisepsis scabra*	129	8	6.2
	Palaeosepsis spp.	1611	101	6.3
	Sarcophagula occidua	2893	5	0.2
	*Sphaeroceridae sp.	37	1	2.7
Total		4670	115	2.5
buffalo feces				
Total	*Palaeosepsis* spp.	1948	19	0.1

Notes: *Morphospecie

Figure 25. *Anastrepha fraterculus* (Wiedemann, 1830) (Diptera: Tephritidae). Source: https://www.invasive.org/browse/detail.cfm?imgnum=5484427

Figure 26. *Aganaspis nordlanderi* Wharton, 1998 . Source: https://www.epagri.sc.gov.br/index.php/tag/aganaspis-nordlanderi

the first record of *A. nordlanderi* in the state of Santa Catarina[28].

3.6 Study 6

The species *Zaeucoila unicarinata* Ashmead, 1903, is a parasitoid of Agromyzidae dipterans. The Zaeucoilini tribe includes 40 species, and its greatest diversity is found in the Neotropical region. Also, according to the same author, the genus *Zaeucoila* is distributed in southern Canada, the United States, Central American countries and South America (Figures 27 and 28).

Zaeucoila is a coinobiont endoparasitoid, which allows, even parasitized, the hosts continue their development until pupation, when the larva of the parasitoid begins to develop. Coinobiont parasitoids are mostly proovigenic, that is, they do not require food from the host to maximize fecundity. It is a solitary parasitoid of Agromizidae Diptera, which parasitize larvae between the first and second instars, with the adult emerging from the puparium.

This species has shown potential to be used in the biological control of *Liriomyza sativae* Blanchard, 1938 (Diptera: Agromyzidae), as it proves to be well adapted to the climatic conditions in its area of natural occurrence, does not have negative impacts on non-target hosts and does not present a risk of competitive exclusion between native versus introduced species (Figure 29).

However, although entomophagous insects are essential for maintaining the population balance of phytophagous insects, these usually occur in insufficient quantity to promote effective control of insect pest populations. Due to this, it is necessary to carry out periodic releases to provide the maintenance of populations of natural enemies for pest control[29-38].

3.7 Study 7

3.7.1 Family Figitidae from Ecuador (South America)

Figitidae is a family of parasitoid wasps. 1,400 species have been described in more than 130 genera, but many remain to be described. For example, the largest subfamily, Eucoilinae (previously considered a separate family, Eucolidae or placed within Cynipidae) has over 1,000 described species but this is thought to be only a fraction of the total diversity. Species of Figitidae are distributed throughout the world (Figure 30A)[39].

They are parasitoids. They feed on larvae of Diptera

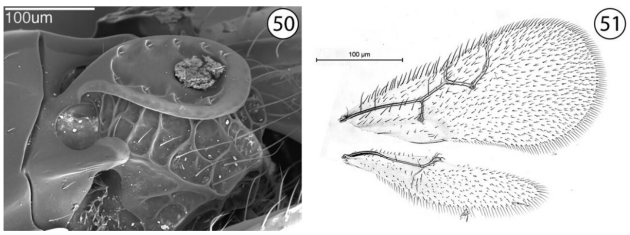

Figure 27. *Zaeucoila flavipes*, new combination. 50: Scutellum, laterodorsal view; 51: Fore and hind wing. Source: https://core.ac.uk/download/pdf/237210329.pdf

Figure 28. *Zaeucoila unicarinata* (Ashmead, 1903). Source: https://eol.org/pages/3831520

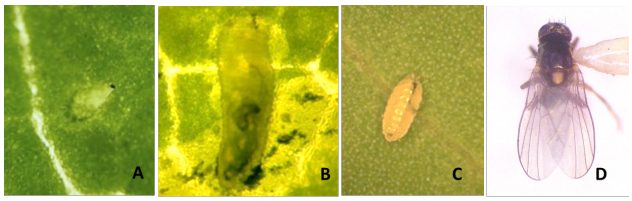

Figure 29. The developmental stages of the vegetable leafminer, *Liriomyza sativae*. A: Egg; B: Larva; C: Pup; D: Adult. Source: https://cipotato.org/riskatlasforafrica/liriomyza-sativae

or Hemerobiidae and Chrysopidae (Neuroptera) or Syrphidae (Diptera); of cynipoid or chalcidoid gall wasps; or from Braconidae or Chalcidoidea that parasitize Hemiptera (Figure 30B).

3.7.2 Systematic

Subfamilies: subfamilies: Anacharitinae, Aspicerinae, Charipinae, Emargininae, Euceroptrinae, Eucoilinae, Figitinae, Mikeiinae, Parnipinae, Plectocynipinae, Pycnostigminae and Thrasorinae.

3.8 Study 8

The objective of this study is to verify the dipteran species and their parasitoids in cattle feces in Goiás, Brazil.

In period from June to October 2003, two specimens of the parasitoid *Kleidotoma nigra* (*Hartig*, 1840) (Hymenoptera: Figitidae) were obtained from 21 pupae of *Brontaea quadristigma (Thomson, 1869)* (Diptera: Muscidae). The percentage of parasitism was 9.5%

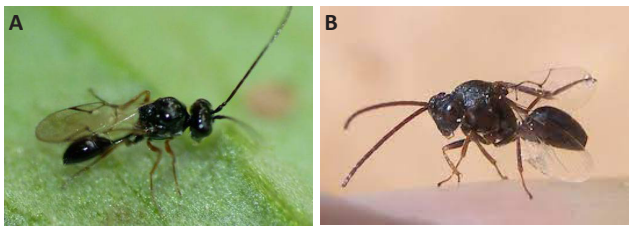

Figure 30. Specimens of Figitidae family from Ecuador (A and B). Source: https://www.biodiversity4all.org/photos/1419238 and https://pt.wikipedia.org/wiki/Figitidae

Figure 31. *Kleidotoma nigra* (Hartig, 1840) (Hymenoptera: Figitidae). Source: https://www.commanster.eu/Commanster/Insects/Bees/SuBees/Kleidotoma.nigra.html

(Figure 31).

Kleidotoma nigra in Brazil was found in pupae of *Palaeosepsis* spp. (Diptera: Sepsidae) in the states of Mato Grosso do Sul and Goiás. This paper reports the first occurrence in Brazil of the species *K. nigra* as parasitoid *B. quadristigma* (Figure 32)[40].

Eucoilinae (Hymenoptera: Figitidae) are endo-parasitoids koinobionts of Diptera Cyclorrhapha larvae that emerge from the host pupa, belonging to the Figitidae family, Cynipoidea superfamily. Approximately 29 genera and 55 species of Eucoilinae are known in Brazil. Much of the Neotropical Eucolinae fauna has not yet been studied[40].

3.9 Study 9

The aim of this study is to describe the first occurrence of *Paraganaspis egeria* Díaz, Gallardo & Walsh (Hymenoptera: Figitidae: Eucoilinae) as a parasitoid of *Archisepsis scabra* (Loew, 1861) (Diptera: Sepsidae) in Brazil[40].

From May to June 2003, 116 pupae of *A. scabra* were obtained, from which four specimens of the parasitoid *P. egeria* emerged. The percentage of parasitism was 3.4%, probably attributed to variations in the quality and availability of food resources or to the density of hosts (Figure 33)[40].

Natural regulators, such as parasitoids, can be used

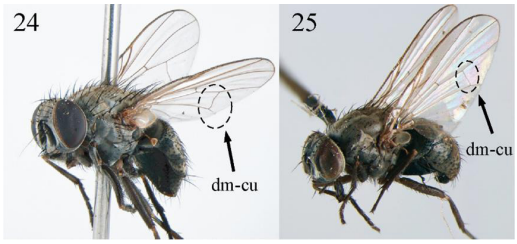

Figure 32. Fronto-lateral view. 24: *Brontaea delecta* (Wulp, 1896) (Diptera: Muscidae); 25: *Brontaea quadristigma* (Thomson, 1869) (Diptera: Muscidae). The dotted line indicates the crossvein dm-cu. Source: https://zenodo.org/record/247777#.Y3fMuXbMLIV

Figure 33. Sarcophagidae main host family of the parasitoid *Paraganaspis egeria* Díaz, Gallardo & Wash 1996, Female. Source: https://www.biodiversity4all.org/photos/90129239

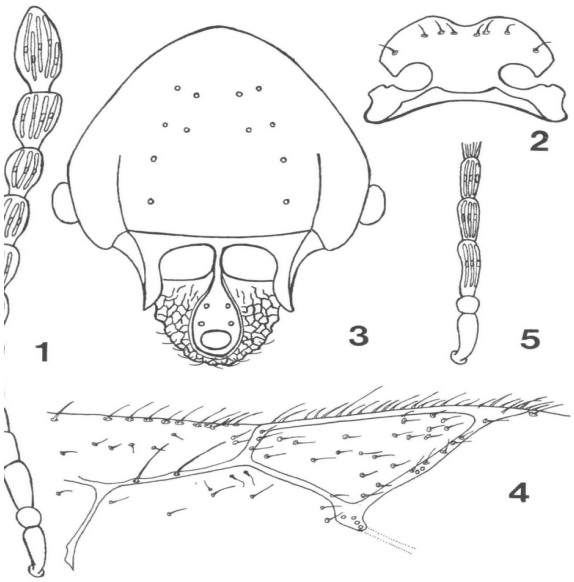

Figure 34. *Paraganaspis egeria* Díaz, Gallardo & Wash 1996. Female. 1: Antenna; 2: Pronotal plate; 3: Mesonotum and scutellum; 4: Detail of the radial cell (anterior wing), male; 5: detail of the antenna. Source: https://www.researchgate.net/figure/5-P-egeria-gen-nov-and-sp-nov-Female-1-antenna-2-pronotal-plate-3_fig1_233642523

in the biological control of flies. These agents are responsible for reducing populations of synanthropic flies. Several species of Eucoilinae have been reported as important natural enemies of different species of Diptera[41].

Paraganaspis egeria was found parasitizing *Chrysomya albiceps* (Wiedemann, 1819) (Diptera: Calliphoridae) in a swine carcass, *Palaeosepsis* spp. (Diptera: Sepsidae) and *Sarcophagula occidua* (Fabricius, 1794) (Fabricius) (Diptera: Sarcophagidae) in bovine faeces and *Fannia pusio* (Wiedemann, 1830) (Diptera: Fanniidae) in human faeces, bovine liver and chicken viscera (Figure 34)[41].

The biology of the Sepsidae family is unknown for the Neotropics. The species of this family are found close to or on animal feces and the larvae develop in decomposing organic matter, being frequent in bovine feces.

This work describes the first occurrence of *P. egeria* as a parasitoid of *A. scabra* in Brazil[41].

3.10 Study 10

The objective of this work is to report the hosts of the parasitoid *Paraganaspis egeria* Díaz, Gallardo & Wash, 1996 (Hymenoptera: Figitidae: Eucolinae) in bovine feces in southern Goiás State[42].

Nine thousand six hundred fifty-seven (9,657) pupae were collected in bovine feces, from which 53 specimens of the parasitoid *P. egeria* emerged (Table 2)[42].

The host species that showed the highest percentage of parasitism in bovine feces was *Haematobia irritans* L., 1758 (Diptera: Muscidae) with 3.6% and in buffalo feces it was the host *Archisepsis scabra* (Loew) (Diptera: Sepsidae) (Table 2) with 1.3%, probably due to the parasitoid's ability to search[42].

Natural regulators, such as parasitoids, can be used in the biological control of flies. These agents are responsible for reducing populations of synanthropic flies. Several species of Eucoilinae have been reported as important natural enemies of different species of Diptera. This study increases the bioecology of the parasitoid *P. egeria* in Brazil[42].

3.11 Study 11

Figitidae present in Germany: Male (♂) about 0.8-5mm / Female (♀) about 0.8-5mm.

Special features: Similar to a gall wasp, but the head and thorax are usually smooth and shiny; Fore wing without pterostigma; Petiolus short to long; Antennae not geniculate, females with 13, males with 11-13 segments. Determination of the species is only possible by a few specialists; the family is poorly processed (Figure 35A).

https://doi.org/10.53964/jmab.2023006

Table 2. Hosts in Percentage of Parasitism of *Paraganaspis egeria* Díaz, Gallardo & Wash, 1996 (Hymenoptera: Figitidae: Eucolinae) from Bovine and Buffalo Feces in Goias, Brazil.

Substrate	Host	Number of Pupae	Parasitized Pupae	%
Cattle dung	Muscidae			
	Cyrtoneurina pararescita	302	02	0.7
	Brontaea quadristigma	720	01	0.1
	Haematobia irritans	28	01	3,6
	Sarcophagidae			
	Sarcophagula occidua	2833	47	1.7
	Sepsidae			
	Palaeosepsis spp.	107	02	1.9
Buffalo feces				
	Muscidae			
	Brontaea quadristigma	138	01	0.7
	Sarcophagidae			
	Sarcophagula occidua	931	11	1.2
	Sepsidae			
	Archisepsis scabra	310	04	1.3
	Palaeosepsis spp.	1948	12	0.6

Notes: The total percentage of parasitism was 0.5%. Regarding buffalo feces, 3,473 pupae were collected, from which 28 specimens of *P. egeria* emerged. The total percentage of parasitism was 0.8%.

Figure 35. Eucoilinae. A: Female (♀) Eucoilinae, *Kleidotoma* specie; B: Female (♀) Eucoilinae. Source: https://www.naturspaziergang.de/Parasitica/Figitidae.htm

Where to find: Various biotopes.

When to find: Around May to September.

The species of the family Figitidae are small, mostly black parasitoid wasps, which are very close to the gall wasps (Cynipidae). About 105 species are known in Germany. But there are probably more. The family is marginally studied worldwide, and little is known about their biology. The only thing that is clear is that the larvae of the figitids are parasitoids in the larvae of various insects (Figure 35B).

The Figitidae are divided into nine subfamilies. The photos show a representative of the subfamily Eucoilinae. According to current knowledge, this subfamily is also the most species-rich. The Eucoilinae species are parasitoids in the larvae of various Diptera (flies).

Subfamílias (mundial): Anacharitinae, Aspericinae, Charipinae, Emargininae, Eucoilinae, Figitinae, Parnipinae, Picnostigminae and Thrasorinae.

Food: Imago: honeydew, nectar; some species do not take food as imagines larvae: parasitoids[43].

4 CONCLUSION

From this study, we derived the bioecology, the bionomy, the biogeography, the life cycle, the hosts, the taxonomy, the phylogeny and the geographic distribution of the family Figitidae. Therefore, contributing to the knowledge of expanding this family, while diagnosing possible native natural enemies, mainly parasites, is vital to avoid possible environmental impacts of classical biological control, such

as migration or even extinction of native species.

Acknowledgements

Thanks to the editors and their working group for publishing the article in the *Journal of Modern Agriculture and Biotechnology*.

Conflicts of Interest

The author declared no conflict of interest.

Author Contribution

Marchiori CH contributed to the manuscript and approved the final version.

References

[1] Buffington ML, Nylander JAA, Heraty JM. The phylogeny and evolution of Figitidae (Hymenoptera: Cynipoidea). *Cladistics*, 2007; 23: 403-431. DOI: 10.1111/j.1096-0031.2007.00153.x

[2] Mattias F, Goran N, Buffington ML. Eucoilinae of North America: A revised catalog of genera and described species. *Proc Entomol Soc Wash*, 2013; 115: 225-255. DOI: 10.4289/0013-8797.115.3.225

[3] Paretas-Martínez J, Restrepo-Ortiz C, Buffington M et al. Systematics of Australian Thrasorinae (Hymenoptera, Cynipoidea, Figitidae) with descriptions of Mikeiinae, new subfamily, two new genera, and three new species. *ZooKeys*, 2011; 108: 21-48. DOI: 10.3897/zookeys.108.829

[4] Ferrer-Suay M, Selfa J, Pujade-Villar J. First record of *Alloxysta* Förster from Madagascar, with descriptions of two new species (Hymenoptera: Cynipoidea: Figitidae: Charipinae). *Afr Entomol*, 2012; 20: 222-228. DOI: 10.4001/003.020.0208

[5] Aguiar AP, Deans AR, Engel MS et al. Order Hymenoptera. Animal biodiversity: An outline of higher-level classif, and survey of taxonomic richness. *Zootaxa*, 2013; 3703: 51-62. DOI: 10.11646/zootaxa.3703.1.12

[6] Buffington F, Liljeblad T, van Noort S. Lucid matrix key to world subfamilies of Figitidae. Accessed July 30, 2020. Available at http://www.waspweb.org/cynipoidea/figitidae/index.htm

[7] van Noort S. WaspWeb: Hymenoptera of the Afrotropical region. Accessed July 30, 2022. Available at http://www.waspweb.org/

[8] Diaz NB, Gallardo FE, Marchiori CH et al. Cynipoidea parasitoids of dung-flies in Brazil. II (Insecta: Hymenoptera). *An Soc Entomol Brasil*, 2000; 29: 469-474. DOI: 10.1590/S0301-80592000000300009

[9] Aluja M, Lopez M, Sivinski J. Ecological evidence for diapause in four native and one exotic species of larval-pupal fruit fly (Diptera: Tephritidae) parasitoids in tropical environments. *Ann Entomol Soc Am*, 1998; 91: 821-833. DOI: 10.1093/aesa/91.6.821

[10] Buffington ML, Giorgini M, Lue CH et al. Description of the aberrant *Leptopilina lasallei* nov. sp., with an updated phylogeny of *Leptopilina* Förster (Hymenoptera: Figitidae: Eucoilinae). *J Nat Hist*, 2020; 54: 565-583. DOI: 10.1080/00222933.2020.1754483

[11] van Noort S. WaspWeb: Wasps, bees and ants of Africa and Madagascar. Accessed July 27, 2022. Available at http://www.waspweb.org/afrotropical_wasps/index.htm

[12] Jordão B, Paranhos D, Edson NA et al. Fruit flies of economic importance in Brazil. Basic and applied knowledge, 1st ed. Holos Editora: Ribeirão Preto, Brazil, 2000.

[13] van Noort S. WaspWeb: Keys to cynipoid wasps of the Afrotropical region. Accessed July 27, 2022. Available at http://www.waspweb.org/Cynipoidea/Keys/index.htm

[14] Soares AS, Boas JCV, Silva RJ. Faunistic analysis and population fluctuations of Eucoilinae in pineapple culture in Araguatins, TO. *Rev Bras Ciênc Ambient*, 2018; 20: 6-20. DOI: 10.7867/1983-1501.2018v20n1p6-20

[15] Guimarães JA, Diaz NB, Gallardo FE et al. Eucoilinae species (Hymenoptera: Cynipoidea: Figitidae) parasitoids of fruit-infesting dipterous larvae in Brazil: Identify, geographical distribution and host associations. *Zootaxa*, 2003; 278: 1-23. DOI: 10.11646/zootaxa.278.1.1

[16] Austin AD, Dowton M. The Hymenoptera: Evolution, biodiversity and biological control, 1st ed. CSIRO Publishing: Melbourne, Australia, 2000. DOI: 10.1071/9780643090088

[17] Ovruski SM, Aluja M, Sivinski J et al. Hymenopteran parasitoids on fruit-infesting Tephritidae (Diptera) in Latin America and the southern United States: Diversity, distribution, taxonomic status and their use in fruit flyt biological control. *Integrated J Integr Pest Manag*, 2000; 5: 81-107. DOI: 10.1023/A:1009652431251

[18] Buffington ML. The occurrence and phylogenetic implications of the ovipositor clip within the Figitidae (Insecta: Hymenoptera: Cynipoidea). *J Nat Hist*, 2007; 41: 2267-2282. DOI: 10.1080/00222930701579732

[19] Ferrer-Suay M, Selfa J, Pujade-Villar J. A review of *Alloxysta* species (Hymenoptera: Cynipoidea: Figitidae: Charipinae) from Africa. *Afr Entomol*, 2013; 21: 255-266. DOI: 10.4001/003.021.0222

[20] Allemand R, Lemaitre C, Frey F et al. Phylogeny of six African *Leptopilina* species (Hymenoptera: Cynipoidea, Figitidae), parasitoids of *Drosophila*, with description of three new species. *Ann Soc Entomol France*, 2002; 38: 319-332. DOI: 10.1080/00379271.2002.10697346

[21] Buffington ML, Forshage M, Liljeblad J et al. World cynipoidea (Hymenoptera): A key to higher-level groups. *Insect Syst Divs*, 2020; 4: 1-69. DOI: 10.1093/isd/ixaa003

[22] Buffington ML. Description, circumscription and phylogenetics of the Diglyphosematini Belizin, 1961, and the description of a new genus (Hymenoptera: Figitidae: Eucoilinae). *Proc Entomol Soc Wash*, 2011; 113: 239-290. DOI: 10.4289/0013-8797.113.3.239

[23] Marchiori CH. Biology and feeding behavior of ceratopogonid adult (Diptera: Ceratopogonidae). *Int J Frontier Technol*, 2021; 1: 7-24. DOI: 10.53294/ijfstr.2021.1.2.0073

[24] Guimarães JA, Zucchi RA, Diaz NB et al. Species of Eucoilinae (Hymenoptera: Cynipoidea: Figitidae) parasitoids of frugivorous Larvae (Diptera: Tephritidae and Lonchaeidae) in Brazil. *An Soc Entomol Bras*, 1999; 28: 263-273. DOI: 10.1590/S0301-80591999000200009

[25] Fernandes DRR. New record of *Zamischus brasiliensis* Ashmead, 1903 (Hymenoptera: Figitidae) in the Brazilian Amazon. *Biota Amaz*, 2019; 2: 56-58.

[26] Petry S, Santos CDR, Sampaio MV et al. Hymenoptera parasitoidism in aphids (Hemiptera: Aphididae) in cabbage leaf. Accessed July 27, 2022. Available at https://eventos.uceff.edu.br/eventosfai_dados/artigos/enfit-sul-2020/1304.pdf

[27] Marchiori CH. Hosts of *Triplasta atrocoxalis* (Ashmead) (Hymenoptera: Figitidae: Eucoilinae) collected in cattle and buffalo dung in Brazil. *Arq Bras Med Vet Zootec*, 2008; 60: 775-777. DOI: 10.1590/S0102-09352008000300039

[28] Santos JP, Guimarães JA. Parasitoids associated with the South American fruit fly: First record of *Aganaspis nordlanderi* (Hymenoptera: Figitidae) in Santa Catarina: National Seminarian temperate fruit growing. Epagri-Sede Press: Florianopolis, Brazil, 2017.

[29] Fergusson NDM. RES Handbooks for the identification of British insects, 8th ed. Royal Entomological Society: St Albans, UK, 1986.

[30] van Noort S. WaspWeb: *Aganaspis nordlanderi* Wharton, 1998. Accessed July 27, 2022. Available at http://www.waspweb.org/Cynipoidea/Figitidae/Eucoilinae/Aganaspis/Aganaspis_nordlanderi.htm

[31] Buffington ML, Gallardo F, Reche VA et al. A Revision of *Zaeucoila* Ashmead (Hymenoptera, Figitidae), parasitoids of Agromyzidae (Diptera): New species, identity, distribution, and hosts. *Proc Entomol Soc Wash*, 2007; 119: 317-397. DOI: 10.4289/0013-8797.119.3.317

[32] Aluja M. Bionomics and management of *Anastrepha*. *Annu Rev Entomol,* 1994; 39: 155-178. DOI: 10.1146/annurev.en.39.010194.001103

[33] Nunes Santos WGN, Fernandes EC, Souza MM et al. First record of Eucoilinae (Hymenoptera: Figitidae), parasitoids of African fig fly *Zaprionus indianus* Gupta (Diptera: Drosophilidae), in the Caatinga biome. *Semin Cienc Agrar*, 2016; 37: 3055-3058. DOI: 10.5433/1679-0359.2016v37n5p3055

[34] Buffington ML, Brady SG, Morita S et al. Divergence estimates and early evolutionary history of Figitidae (Hymenoptera: Cynipoidea). *Syst Entomol*, 2012; 37: 287-304. DOI: 10.1111/j.1365-3113.2012.00617.x

[35] Parra JRP. Biological control in Brazil: Parasitoids and predators, 1st ed. Editora Manole Ltda: Barueri, Brazil, 2002.

[36] Quicke DLJ. Biology, systematics, evolution and ecology of braconid and ichneumonid parasitoid wasps, 1st ed. Wiley Blackwell: Nova Jersey, USA, 2015. DOI: 10.1002/9781118907085

[37] Cunha RSM. Developmental time and morphological characterization of *Zaeucoila unicarinata* Ashmead (Hymenoptera: Figitidae) on *Liriomyza sativae* (Diptera: Agromyzidae) larvae [master's thesis]. Mossoró, Brazil: Universidade Federal Rural do Semi-Arído; 2021.

[38] Santos CDR, Sampaio MV, Ferrer-Suay M et al. First record of *Phaenoglyphis villosa* (Hartig, 1841) in Brazil (Hymenoptera: Cynipoidea: Figitidae: Charipinae). *Entomol Commun*, 2008; 2: ec02008. DOI: 10.37486/2675-1305.ec02008

[39] Familia Figitidae iNaturalist Ecuador Wikipedia. Accessed July 27, 2022. Available at https://ecuador.inaturalist.org/taxa/203209-Figitidae

[40] Marchiori CH. First occurrence of the parasitoid *Kleidotoma nigra* (Hartig) (Hymenoptera: Figitidae: Eucoilinae) in pupae of *Brontaea quadristigma* (Thomson) (Diptera: Muscidae) in bovine feces in Brazil. *Qeios*, 2020; 71: 70-71. DOI: 10.32388/IX749A

[41] Marchiori CH. First report of the parasitoid *Paraganaspis egeria* Díaz, Gallardo & Walsh (Hymenoptera: Figitidae: Eucolinae) as a natural enemy of *Archisepsis scabra* (Loew) (Diptera: Sepsidae) in buffalo feces in Brazil. *Arq Bras Med Vet Zootec*, 2005; 57: 273-274. DOI: 10.1590/S0102-09352002000600019

[42] Marchiori CH. Hospedeiros do parasitóide *Paraganaspis egeria* Díaz, Gallardo & Walsh (Hymenoptera: Figitidae: Eucoilinae) coletados em fezes bovinas e de búfalos, no sul do estado de Goiás. *Cienc Agrotec*, 2009: 33: 1898-1900. DOI: 10.1590/S1413-70542009000700034

[43] Figitidae spec. ("Parasitica"). Accessed July 30, 2022. Available at https://www.naturspaziergang.de/Parasitica/Figitidae.htm