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(REVIEW ARTICLE)

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Mini review of parasitoids collected in biomes and morphoclimatic domains in Brazil

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Abstract

In Brazil we can find six types of biomes: Amazon, Atlantic Forest, Cerrado, Caatinga, Pampa, Pantanal, and two morphoclimatic domains: the Araucaria Forest the Mata from Cocais. Our biomes and morphoclimatic domains are important not only as natural resources in our country but stand out as environments of great natural wealth on the planet. The aim of this study is to describe the parasitoids collected in Brazilian biomes. The mini review consists of a bibliographic summary of parasitoids of the Order Hymenoptera parasitoids collected in the following Biomes and morphoclimatic domain in Brazil. The research was carried out in studies related to the theme with emphasis on the quantitative aspects of the superfamily, family, subfamilies, genera, and species (Taxonomic groups). A bibliographic search was carried out that contained papers published from 2006 to June 2021.The mini review was prepared in Goiânia, Goiás from March to June 2021using the Electronic Scientific Library Online (Scielo) and internet. This biodiversity can offer unique opportunity for pest control in both Brazil and other countries, due to the identification of new organisms with potential to be used in biological control.

Keywords: Insect; Hymenotera; Biocontrol; Natural enemy; Bibliographic summary

1. Biomes and morphoclimatic domain in Brazil

Figure 1 Brazilian Biomes: Amazon (green), Caatinga (yellow), Cerrado (pink), Pantanal (lilac), Atlantic Forest (water green) and Pampa (pastel yellow) **Source**: brasilescola.uol.com.br/brasil/biomas-brasileiros.htm.

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In our country, we can find six types of biomes: Amazon, Atlantic Forest, Cerrado, Caatinga, Pampa and Pantanal. Our Biomes are important not only as natural resources in our country but stand out as environments of great natural wealth on the planet (Figure 1) [1].

The Amazon Biome (Figure 2) occupies about 49% of the Brazilian territory. The Amazon has the largest tropical forest in the world, equivalent to 1/3 of the humid tropical forest reserves that are home to the largest number of species of flora and fauna. Contains 20% of the world's availability of water and large mineral reserves. The delicate balance of their life forms is very sensitive to human interference [1].

Figure 2 Amazonia Biome; **Source**: https://www.poder360.com.br/opiniao/brasil/a-amazonia-exige-soberania-4-0-escreve-paulo-hartung/.

The Atlantic Forest Biome (Figure 3) occupies approximately 13% of the Brazilian territory. As it is located in the coastal region, occupied by more than 50% of the Brazilian population, it is the most threatened Biome in Brazil. Only 27% of its original forest cover is still preserved [1].

Figure 3 Atlantic Forest Biome; **Source:** ema.ce.gov.br/2020/05/27/mais-uma-vez-no-ceara-o-desmatamento-na-mata-atlantica-e-zero/.

The Cerrado Biome (Figure 4) occurs mainly in the Brazilian Central Plateau and occupies approximately 24% of the Brazilian territory. The Cerrado is recognized as the richest savannah in the world in terms of biodiversity. Until the 1950, the Cerrados remained almost unchanged. From the 1960, with the transfer of the Federal Capital, from Rio de Janeiro to Brasília, and the opening of a new road network, the natural vegetation cover gave way to cattle raising and intensive Agriculture [1]. The Pampa Biome (Figure 5) occupies approximately 2% of the National Territory. It is characterized by a rainy climate, without a dry period, but with negative temperatures in winter, which influence the vegetation [1].

Figure 4 Cerrado Biome; **Source:** https://brasilescola.uol.com.br/brasil/cerrado.htm.

Figure 5 Pampa Biome; **Source**: https://marsemfim.com.br/bioma-pampa-e-a-indiferenca-da-opiniao-publica/.

Figure 6 Pantanal Biome;

Source: https://mail.yahoo.com/d/folders/1/messages/aolcpe8gcfh2xliueq5radpzzom?.lang=pt-br.

Throughout the area covered by the Pampa Biome, human activity has provided a uniformity of vegetation cover, which in general is used as natural pasture or occupied with agricultural activities, mainly rice cultivation [1].

The Pantanal Biome (Figure 6) occupies approximately 2% of the National Territory. However, the Pantanal Biome is recognized as the largest continuous floodplain on Planet Earth, which is the main factor for its formation and differentiation in relation to other biomes. There, representatives of almost all Brazilian fauna gather. The Pantanal Biome is the most preserved, although cattle raising is an economically important activity for the region, together with tourism activities [1].

1.1. The morphoclimatic domains

Represent the combination of a set of elements of nature, relief, climate and vegetation that interrelate and interact, forming a landscape unit.

1.1.1. The Araucaria Forest (morphoclimatic domain)

The Araucaria Forest (Figure 7) is a plant formation that, as the name says, is characterized by the presence of *Araucaria angustifolia* (Bertol.) Kuntze (Araucariaceae) (Pinheiro-do-Paraná or Araucaria). It is an Atlantic Forest ecosystem and occurs in southern Brazil, extending through the states of Paraná, Santa Catarina and Rio Grande do Sul and in sparse patches in São Paulo and Minas Gerais [2].

Figure 7 Araucaria Forest; **Source:** http://institutopuruna.com.br/the-beauties-and-riches-of-araucaria-forest/

1.1.2. The Cocais Forest

Cocais Forest (Figure 8) is a type of Brazilian vegetation that occurs between the North and Northeast regions of Brazil, called the mid-north region.

Figure 8 Cocais Forest**; Source**: https://www.todamateria.com.br/mata-dos-cocais/

It corresponds to a transition area involving several distinct states and vegetations. In the region where the mid-north is located, it is possible to identify very different climates, such as equatorial super-humid and semi-arid [3].

The is composed of babassu, carnauba, oiticica and buriti; it is established between the Amazon and the caatinga, covering the states of Piauí and Maranhão.

2. Parasitoids

Parasitoids are exceedingly small insects that live for at least part of their life inside a host. This host is usually another insect (usually the pest of the crop) that ends up dying from parasitism (Figure 9 a, b, c, d and e) [4].

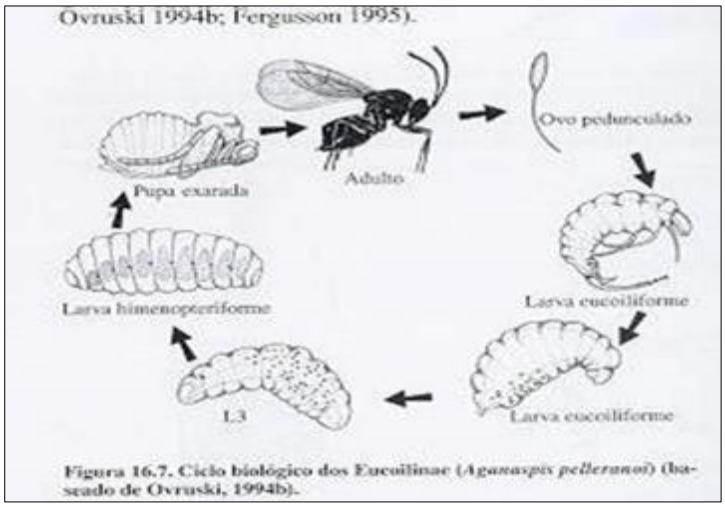

Figure 9 (a) Life cycle of Eucoilinae of *Aganaspis pelleranoi* (Brèthes, 1924) (Hymenoptera: Figitidae)**. Source:** Ioriatti MCS. Contribution to the Study of the Biology and Taxonomy of the Hymenoptera (Braconidae, Diapriidae, Eucoilidae and Pteromalidae) Parasitoids of the Fruit Fly (Diptera, Tephritidae and Lonchaeidae). 1995. Thesis (Doctorate in Ecology and Natural Resources) - Federal University of São Carlos Brazil.

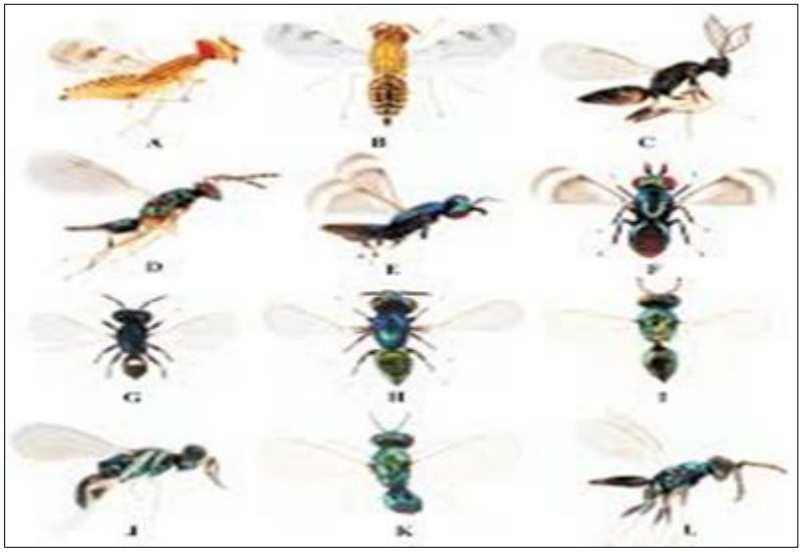

Figure 9(b) (A, B C, D, E, F, G, H, I, J, K and L) Groups of parasitoids (Hymenoptera);
Source: https://www.researchgate.net/figure/Figura-3-Especies-de-parasitoides-de-Leucoptera-coffeella-en-el-departamento-de_fig4_305777321.

These parasitoids may prefer different stages of pest development (eggs, larvae, pupae or adults); however, egg parasitoids are noteworthy for killing the pest still in the egg, a stage prior to any type of damage that the insect pest could cause in the crop. Among the different egg parasitoids, *Trissolcus basalis* (Wollaston) and *Telenomus podisi*

Ashmead (Hymenoptera: Scelionidae) and *Trichogramma* spp. (Hymenoptera: Trichogrammatidae) they are the most studied in the soybean crop and with the greatest control potential [4].

These "waps" occur naturally in the field and can also be bred in the laboratory and massively released in applied biological control programs, however, they are quite sensitive to insecticides, especially those with a broad spectrum of action such as pyrethroids and organophosphates that must be used whenever avoided. On the other hand, insecticides from the group of insect growth regulators (the so-called “physiological ones”) are generally selective and their use on soybeans can be in most cases compatible with the action of the parasitoids [4].

The mini review consists of a bibliographic summary of parasitoids of the Order Hymenoptera collected in the following biomes and morphoclimatic domain in Brazil.

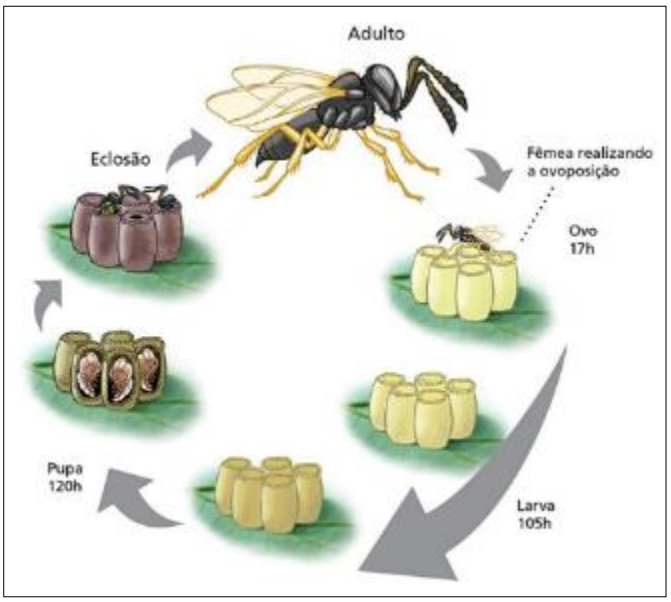

Figure 9 (c) Life cycle of an egg parasitoid: female parasitoid performing oviposition, egg, larva, pupa and adult. Life cycle of *Telenomus podisi* (Ashmead, 1893) (Hymenoptera: Scelionidae) are in eggs of brown stink bug *Euschistus heros* (Fabricius, 1798) (Heteroptera: Pentatomidae); **Source**: Koppert Biological Syatema (http://www.koppert.com.br/podisbug/).

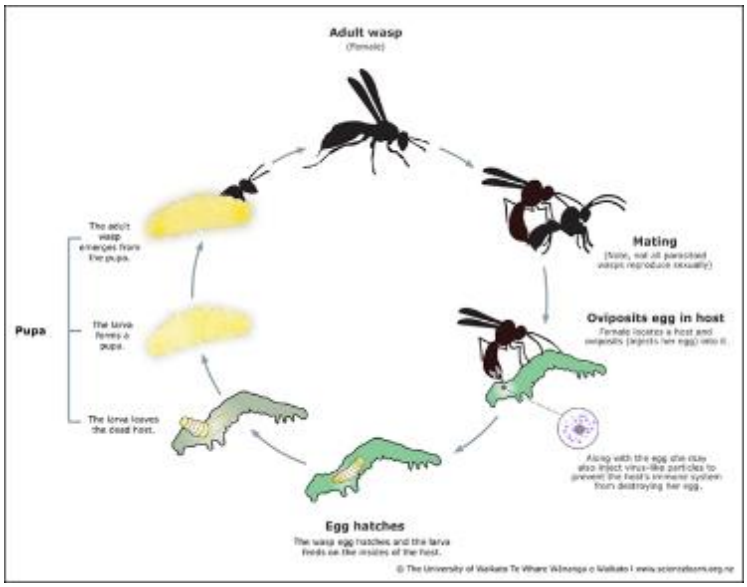

Figure 9d Life cycle of a larval parasitoid: copula, female ovipositing in an insect larva, egg, larva, pupa and adult emergence; **Source**: https://www.sciencelearn.org.nz/resources/2770-parasitoid-wasp-life-cycle.

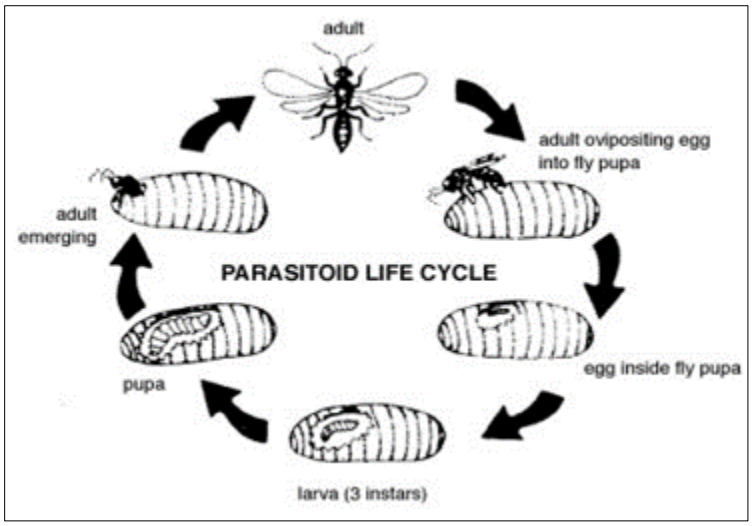

Figure 9e Life cycle of a pupal parasitoid;

Source: https://biocontrol.entomology.cornell.edu/parasitoids/muscidifurax.php.

The aim of this study is to describe the parasitoids collected in Brazilian biomes.

3. Methods

The mini review consists of a bibliographic summary of parasitoids of the Order Hymenoptera collected in the following Biomes: Amazon, Caatinga, Cerrado, Pampa, Atlantic Forest and morphoclimatic domain the Araucaria Forest the Mata from Cocais. The research was carried out in studies related to the theme with emphasis on the quantitative aspects (Objectives and Results) of the superfamily, family, subfamilies, genera, and species. (Taxonomic groups). The mini review was prepared in Goiânia, Goiás, Brazil from 2007 to 2021, using the Electronic Scientific Library Online (Scielo) and internet.

4. Experimental Studies

4.1. Atlantic Forest

4.1.1. Study 1

The objective of this work was to contribute to the knowledge of the fauna of Hymenoptera parasitoids that occur in rubber plantations, comparing their abundance in areas of riparian forest and cerrado. Two Malaise traps were installed, respectively, in two plots of rubber tree cultivation, clone PR 225, at the Michelin Farm, from November 4, 2005, to February 10, 2006, with collections every two weeks.

Figure 10 Exemplary of the Bethylidae Family; **Source**: https://bugtracks.wordpress.com/tag/bethylidae/.

A total of 2,223 parasitoid Hymenoptera specimens were collected: 1,404 in the plot that borders riparian forest and 819 in the plot that borders savannah. The specimens were distributed into 7 superfamilies, with Chrysidoidea (Bethylidae) (Figure 10) and Ichneumonoidea (Braconidae and Ichneumonidae) being the most abundant in both stands. The specimens belonging to these superfamilies represent 76.92% and 10.89% respectively of the total specimens collected in the riparian forest area and 78.02% and 12.94%, respectively, of the total specimens collected in the cerrado area [5].

4.1.2. Study 2

The study was carried out at the company Cellulose Nipo-Brasileira (CENIBRA) in the municipality of Ipaba (remnants of Atlantic Forest in the State), Minas Gerais, in a plantation of *Eucalyptus grandis* W. Hill ex. Maiden in the Rio Sweet Valley. The parasitoid Hymenoptera were collected with eleven Malaise traps.

Twenty-seven collections were carried out from March 1997 to March 1998, with the capture of 2,099 hymenopterans parasitoids, from nine superfamilies (Ceraphronoidea, Chalcidoidea, Chrysidoidea, Cynipoidea, Evanioidea, Ichneumonoidea, Platygastroidea, and Poctotrupoidea) and 26 families. The most abundant superfamilies were Ichneumonoidea and Chalcidoidea, with 1,029 and 507 individuals, which represented 49.02 and 24.15% of the total collected, respectively. The families Ichneumonidae and Braconidae had higher numbers of individuals (577 and 452), representing 27.49 and 21.53% of the collected parasitoids, respectively. The superfamily Chalcidoidea had individuals from 12 families (Chalcididae, Encyrtidae, Eucharitidae, Eulophidae, Eupelmidae, Eurytomidae, Mymaridae, Perilampidae, Pteromalidae, Signiphoridae, Torymidae (Figure 11) and Trichogrammatidae), with Eulophidae (1881) having higher numbers of 81% of individuals [6].

Figure 11 Exemplary of the Torymidae Family; **Source**: https://www.flickr.com/photos/m-a-r-t-i-n/18803664411.

4.1.3. Study 3

This work aims to raise the hymenopteran fauna in the gallery forest contained in the pasture matrix, using Moericke-type traps, over a twelve-month period, in the city of Pratápolis (MG).

Figure 12 Exemplary of the Diapriidae Family; **Source:** https://bugguide.net/node/view/1722781/bgimage.

A total of 1814 specimens of hymenopteran were collected, distributed in 10 Superfamilies (except Chalcidoidea) and 21 families. Of these, 13 were families of parasitoids, totaling 696 specimens (38.37%), distributed as follows:

Diapriidae, 324 specimens (Figure 12) (17.86%); Ichneumonidae, 116 specimens (6.39%); Braconidae, 115 specimens (6.34%); Ceraphronidae, 65 specimens (3.60%); Platygastridae, 30 specimens (1.65%); Cynipidae, 15 specimens (0.83%); Scelionidae, 13 specimens (0.72%); Bethylidae, 07 specimens (0.39%); Dryinidae, 05 specimens (0.28%); Evaniidae 03 specimens (0.16%); Megaspilidae, Ibaliidae and Scolebythidae, 01 specimen each (0.05%) [7].

4.1.4. Study 4

This study aimed to verify whether the presence of Atlantic Forest remnants around eucalyptus plantations affects the rates of infestation of *Euselasia apisaon* (Dahman) (Lepidoptera: Riodinidae) and parasitism of its eggs. Its eggs are commonly parasitized by *Trichogramma maxacalii* (Voegelé and Pointel) (Hymenoptera: Trichogrammatidae) (Figure 13).

In 60 *Eucalyptus grandis* W. Hill ex Maiden 1903 (Myrtaceae) branches collected, 88,925 eggs were found in 2008 *E. apisaon* laying (44.3 ± 5.38 eggs per laying). On average, 19.2 ±4.12 eggs per sheet. Considering the two plots together, the center had 43,813 eggs and the edge had 45,112 eggs. The number of eggs per leaf was 1.6 times higher in the center than on the edges of the stands, although the difference was not statistically signifi can't (Student's t test, $P > 0.05$, GL = 58, $t = 0.012$). Of the total eggs, 51,202 (57.6%) larvae had already hatched or hatched during screening, allowing the determination of their survival or parasitism and the capture of adult caterpillars and parasitoids at the time of hatching. Of these, 36,085 (70.5%) were parasitized.

All adult parasitoids obtained from these eggs belonged to the species *T. maxacali*. Considering only the 836 postures, of which all larvae had hatched, the average rate of parasitism by laying was of 73.8 ± 1.4%. In postures located at the edge of plantings with native vegetation, the efficiency of *T. maxacali* was still higher, with an average rate of parasitism of 80.5%. The average rate of parasitism of eggs per laying was significantly higher at the edge of the eucalyptus stands with the Atlantic Forest than at the center of them (Mann Whitney U test, $U = 62044.5$, $P < 0.001$) [8].

Figure 13 Specimens of the Trichogrammatidae Family (Hymenoptera);
Source: https://anatisbioprotection.com/en/news/european-corn-borer-peppers.html.

4.1.5. Study 5

This study aimed to verify and compare the occurrence and composition of Chrysidoidea fauna sampled in agroforestry and conventional coffee production systems located in southeastern Brazil.

A total of 3,623 specimens of Chrysidoidea belonging to three families were collected: Bethylidae with 4 genera and 3,396 individuals, representing 93.73% of the total collected; Chrysididae with 11 genera and 151 individuals (4.16%) and Dryinidae with five genera and 76 individuals (2.09%). Of the 20 Chrysidoidea genera collected, two were restricted to the conventional systems, all of them belonging to Chrysidinae; three genera were restricted to the agroforestry, one of each family, and no genera was collected exclusively in the transitional system. The conventional systems shared with the agroforestry three genera (one of Bethylidae and two of Dryinidae), and three others.

Seven genera were found in the three types of systems, one of Bethylidae, one of Dryinidae, and five of Chrysididae. In terms of abundance, the agroforestry systems were responsible for most of the individuals collected (n = 2029), followed by the conventional systems with 1,406 individuals and the transitional with 188. Approximately 92% of this amount is because of the bethylid genera *Epyris* and *Dissomphalus*. Bethylidae was the most abundant Chrysidoidea family sampled in several other studies of Hymenoptera parasitoids. *Epyris* Westwood was the most abundant genus of

Bethylidae, collected in all the environments, representing approximately 69% of all individuals collected in the three systems.

The second genus with higher abundance was *Dissomphalus* Ashmead, representing approximately 23% of the total specimens collected. The genus *Bakeriella* Kieffer (Figure 14) occurred in both agroforestry and transitional systems. The genus *Goniozus* Förster occurred in the conventional and agroforestry systems. in relation to the others bethylids collected, representing 1,7% of the total collected individuals. The genus *Bakeriella* Kieffer occurred in both agroforestry and transitional systems [9].

Figure 14 Exemplary of the *Bakeriella* Kieffer (Hymenopter: Chrysidoidea);

Source: https://www.biotaxa.org/Zootaxa/article/view/zootaxa.3878.6.1.

4.1.6. Study 6

To know the trophic associations between the parasitoid species and fruit flies in the Serra da Bodoquena National Park (PNSB), Brazil; to inventory the parasitoid species associated with fruit flies in fruit trees in the PNSB.

Twenty-three adult parasitoids were recovered from the tephritid larvae, represented by two Braconidae species: *Doryctobracon areolatus* (Szépliget) (Hymenoptera: Braconidae) (18) and *Utetes anastrephae* (Viereck) (Insecta: Hymenoptera: Braconidae) (5) (Figure 15), both infesting *Anastrepha* species: *Anastrepha fraterculus* (Wiedmann), *Anastrepha sororcula* Zucchi and *Anastrepha striata* Schiner in Myrtaceae: *Psidium guajava* L.

Figure 15 *Utetes anastrephae* (Viereck, 1913) (Hymenptera: Braconidae);

Source: https://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=390857.

The higher abundance of parasitoids occurred in *Eugenia myrcianthes* Nied (Myrtaceae), with 10 individuals of *D. areolatus* and three of *U. anastrephae*. In *P. guajava*, eight adults of *D. areolatus* and two from *U. anastrephae* were

obtained. The highest parasitism index was obtained in *E. myrcianthes*, with 6.5% of parasitism, and in *P. guajava* the index was 6%, totalizing 12.5% of parasitized larvae [10].

4.2. The Caatinga biome

4.2.1. Study 1

The aim of this study is to contribute to the knowledge of the diversity of parasitoid wasps (Hymenoptera) existing in the Caatinga biome and to evaluate their attraction to different colors of Moericke traps.

For the knowledge of the diversity of parasitoid wasps using Moericke traps, 1,030 specimens of parasitoid wasps were obtained. The individuals sampled in this work belong to 17 families and are distributed in 7 superfamilies. Chalcidoidea, Icheneumonoidea, Vespoidea-predator), Chrysidoidea, Evanioidea, Platigastroidea and Proctotrupoidae. The most representative superfamilies recorded were: Chalcidoidea (399 specimens), followed by Vespoidea (365 specimens-predator) and Ichneumonoidea (113 specimens).

Seven families were collected, being the Chalcididae (Figure 16) represented by 197 individuals collected in the four points, followed by the Pteromalidae with 71 individuals and others such as Eupelmidae, Eucharytidae, Eulophidae, Eurytomidae and Torytomidae with a smaller number.

In addition, the attraction to different colors of Moericke traps. Twenty-three specimens were collected, belonging to 7 superfamilies with 9 families represented. Among wings, the most abundant families were represented 6 Evaniidae and 5 Ichneumonidae. The families Platigastridae, Scelionidae, Braconidae, and Pteromalidae with 1 specimen collected and Megaspilidae, Diapriidae with 2 specimens and Mymaridae with 3 specimens were considered less abundant. The most attractive yellow tray with 15 individuals represented. The colors green (3 individuals), white (2 individuals), pink (2 individuals) and black (1 individual) were the least attractive in this work [11].

Figure 16 Exemplary of the Chalcididae Family; **Source**: https://bugguide.net/node/view/1344970.

4.3. Study 2

The objective is to study the bioecology of *Doryctobracon areolatus* (Szépligeti, 1911) (Hymenoptera: Braconidae) (Figure 17) in the field, aiming to understand the tritrophic relationship in the northern region of Minas Gerais.

During a period of seven months, 10,442 fruits were collected in domestic orchards in rural areas, belonging to 6 families and 12 plant species. 6,526 puparia of frugivorous flies were obtained in 10 plant species sampled, from which 3,017 adults (fruit flies, parasitoids and Lonchaeidae) emerged. The largest number of puparia (3,091) was obtained from the Anacardiaceae family, representing 47.36% of the total, followed by Myrtaceae (2,845) with 43.59%. Of the fruit flies that emerged, 2,339 belonged to the genus *Anastrepha* (1,246 males and 1,093 females), 359 specimens of *Ceratitis capitata* (Wiedemann, 1824) (Diptera: Tephritidae) (194 males and 165 females), 303 parasitoid braconids (130 males and 173 females) and 16 specimens of the family Lonchaeidae.

A total of 6,526 puparia of frugivorous flies were obtained in 10 plant species sampled, from which 3,017 adults (fruit flies, parasitoids and Lonchaeidae) emerged. The number of specimens of the genus *Anastrepha* obtained was 84.66% higher than the number of individuals of *C. capitata*, representing 77.52% of the total number of insects collected. Parasitoids accounted for 10.05% of the total number of insects obtained and lonqueids (Lonchaeidae) accounted for

only 0.54%. A total of 303 parasitoids of the species *D. areolatus* were obtained from three hosts, guava (Myrtaceae), seriguela and umbu (Anacardiaceae) [12].

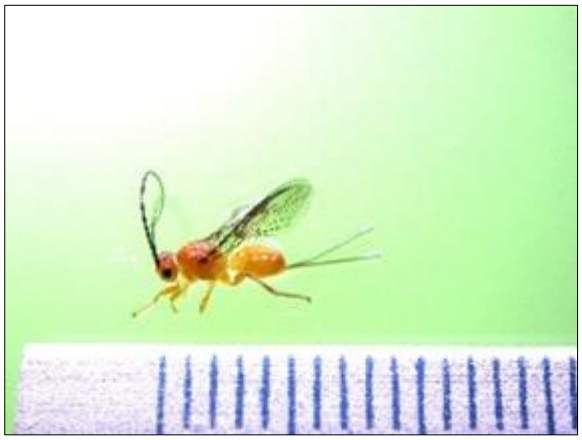

Figure 17 *Doryctobracon areolatus* (Szépligeti, 1911) (Hymenoptera; Braconidae);

Source: https://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=315596.

4.4. Pampa Biome

4.4.1. Study 1

The aim of the study was to verify if the organization of communities of parasitoids and galling species, which induce leaf galls with and without trichomes, are similar.

A total of 651 glabrous galls (Figure 18) were collected for four species and 1,169 hairy galls for four species, from which emerged, respectively, 470 parasitoids of 17 species and 151 of 19 species.

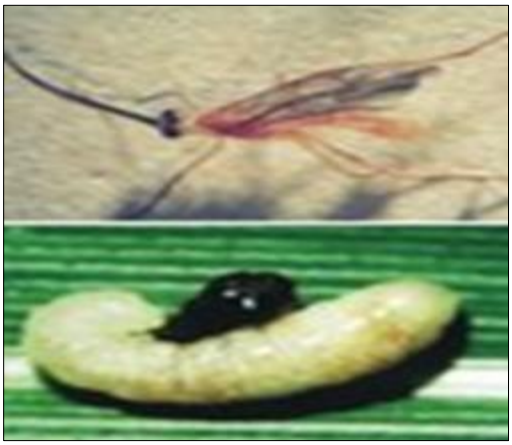

Figure 18 Adult and larvae of the caterpillar parasitoid; **Photo**: Ivan Cruz - Embrapa Milho.

Of the total possible interactions, only 26% (C) occurred in the hairy RIQ and 35% in the glabrous one. The parasitoid assemblage associated with the first showed greater specialization (91%), compared to the second (50%) [13].

4.5. Pantanal Biome

4.5.1. Sudy 1

The aims of this study are to evaluate species richness of hymenopteran parasitoids in frugivorous larvae of different species of Tephritoidea in 3 different environments from Brazil (Cerrado, Pantanal, and Serra de Maracajú).

Three families of parasitoids were recovered: Braconidae (Opiinae), Figitidae (Eucoilinae) and Pteromalidae (Spalangiinae). The opiines attacked larvae of species of *Anastrepha* and/or *Ceratitis capitata* (Wiedemann) (Tephritidae). *Lopheucoila anastrephae* (Rohwer) (Figitidae: Eucoilinae) (Figure19) parasitized larvae of *Neosilba* species (Lonchaeidae) infesting pods of *Inga laurina* (Swartz) (Fabaceae), and *Spalangia endius* (Walker) (Pteromalidae) were obtained from containers with L3 of Tephritidae from samples of *Ximenia americana* L. (Santalales: Olacaceae) fruits.

Figure 19 *Lopheucoila anastrephae* (Rohwer, 1919) (Figitidae: Eucoilinae);
Source: https://www.waspweb.org/Cynipoidea/Figitidae/Eucoilinae/Lopheucoila/Lopheucoila_anastrephae.htm.

The braconids *Doryctobracon areolatus* (Szépligeti) (Hymenoptera: Braconidae) and *Utetes anastrephae* (Viereck) occurred in all 3 environments, but were more abundant and frequent in the Pantanal, but *Opius bellus* (Gahan) emerged only from tephritids feeding in the fruits of *X. americana* from Pantanal. *Lopheucoila anastrepha* occurred in the Serra de Maracajú and *S. endius* only in the Pantanal [14].

4.6. Amazon Biome

4.6.1. Study 1

This work aimed to record the occurrence of *Anastrepha* species, and their parasitoids associated with *Spondias mombin* L. (Anacardiaceae) fruits in three municipalities in the state of Amapá, Brazil.

Figure 20 *Opius bellus* Gahan 1930 (Hymenoptera: Braconidae);

Source: https://treatment.plazi.org/GgServer/html/2F2587AFFFF0C71A8AB8FCA7FB603939.

Four species of the *Anastrepha* genus were obtained: *Anastrepha obliqua* (Macquart) (Diptera: Tephritidae) (279 specimens), *Anastrepha antunesi* Lima (Diptera: Tephritidae) (151 specimens), *Anastrepha fraterculus* (Wiedemann) (Diptera: Tephritidae) (5 specimens) and *Anastrepha striata* Schiner (Diptera: Tephritidae) was *Anastrepha antunesi* Lima (Diptera: Tephritidae) (77 specimens). *A. fraterculus* (5 specimens) was obtained from four samples collected in Mazagão.

Of the 29 samples infested by fruit flies, only seven (24.1% of the total) did not show parasitism. The percentage of parasitism was lower in Oiapoque (mean 2.5% among the parasitized samples) and higher in Mazagão (mean 18.9%). Specimens from two families of Hymenoptera parasitoides of *Anastrepha* were obtained: Braconidae (99.6% of the total) - *Opius bellus* Gahan (132 specimens) (Figure 20), *Doryctobracon areolatus* (Szépligeti) (70), *Asobara anastrephae* (Muesebeck) (43) and *Utetes anastrephae* (Viereck) (15); Figitidae (0.4%) - *Aganaspis pelleranoi* (Brèthes) (1) [15].

4.6.2. Study 2

The aims of this study were to investigate the species richness and abundance of Hymenoptera parasitoids, taking into account their seasonal distribution in the understory and canopy, as well as in the inner forest and on the forest border of an Amazon Forest reserve.

About 12,835 specimens from 23 families of Hymenoptera parasitoids were collected. The most representative in abundance on the border and in the interior areas, as well as in the canopies and understories in the reserve, were Broconidae, Diapriidae, Mymaridae, Eulophidae and Scelionidae.

Eight families Aphelinidae, Braconidae, Ceraphronidae, Chalcididae, Mymaridae, Scelionidae, Torymidae and Trichogrammatidae) were associated with the understory, while only one (Figitidae) was associated with the canopy. Braconidae, Chalcididae, Figitidae, Mymaridae, Sceliondae, Torymidae, and Trichogrammatidae on the border of the reserve border of the reserve, while two families Aphelinidae and Ceraphronidae were associated with the interior. There was an association of seven families (Braconidae, Chalcididae, Figitidae, Mymaridae (Figure 21), Sceliondae, Torymidae and Trichogrammatidae) on the border of the reserve, while two families (Aphelinidae and Ceraphronidae) were associated with the interior. These results indicate the less abundant Hymenoptera families are substituted in one or the other area (interior or border). The occurrence of Aphelinidae and Ceraphronidae tends to indicate the presence in the whole forest [16].

Figure 21 Exemplary of Mymaridae Family; **Source**: https://elp.tamu.edu/ipm/bugs/wasps-sawflies-velvet-ants-2/hymenoptera-mymaridae-neomymar-male-b/.

4.7. Cerrado Biome

4.7.1. Study 1

Thus, the aim of this study was to know and quantify the genera of Braconidae collected with McPhail trap in native and exotic fruit orchards in Jaboticabal, SP.

Figure 22 *Aphaereta* Foster (exodontes jaws to emerge from the pupa)**;**
Source: https://bdj.pensoft.net/article/49017/.

Samplings were carried out weekly, between May 2009 and May 2010, using four plastic McPhail traps with hydrolyzed corn protein bait. 81 braconidia were collected, distributed in five genera of two subfamilies: *Aphaereta* Foster (41 specimens / 51.8% of the total) (Figure 22), *Asobara* Foster (25/30.9%), *Gnathopleura* Fisher (11/13.6%), *Dinotrema* Foster (2/2.5 %) (Alysiinae) and *Opius* Wesmael (1/1.2%) (Opiinae) (Diptera: Braconidae).

However, although some *Asobara* and *Opius* species are important MDF parasitoids, the species captured in this study [17].

4.7.2. Study 2

This research aimed at studying the parasitoid diversity and determine the richness and faunal indices of parasitoids in reforestation of *Tectona grandis* L.f. (Lamiaceae).

One collected 414 specimens belonging to Chalcididae distributed in 3 genera and 16 species. *Conura* with 14 species (90%) was the most representative number of species collected. Quantitatively, *Brachymeria* and *Conura* were the most representative genera, corresponding respectively to 120 and 197 individuals. In faunal analysis of collected and identified individuals in the studied sites, species *Brachymeria pandora* (Crawford) (Hymenoptera, Chalcididae) (Figure 23) and *Ceyxia ventrispinosa* Girault (Hymenoptera: Chalcidade) occurred as the most dominant, abundant, frequent, and constant species.

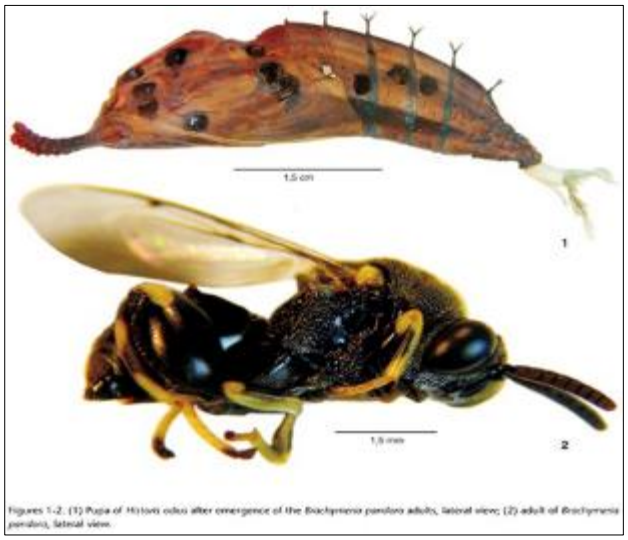

Figure 23 Pupa of *Historis odius* (Fabricius, 1775) (Lepidoptera, Nymphalidae) after emergence of the *Brachymeria Pandora* (Crawford, 1904) (Hymenoptera, Chalcididae) adult; (b) adult of *B. pandora,* lateral view;
Source: https://www.scielo.br/j/rbzool/a/7T7FMHbX8Z3wVQ5s8d6wwTc/abstract/?lang=en.

In faunal analysis of collected and identified individuals in the studied sites, species *B. pandora* and *C. ventrispinosa* occurred as the most dominant, abundant, frequent, and constant species. *Conura maculata* (Fabricius) (Hymenoptera: Chalcididae) and *Conura nigrifrons* (Cameron) (Hymenoptera: Chalcididae) were also important species because they were classified as dominant and associated with the maximum indices of abundance, frequency, and constancy. 3, *Conura* sp.4 and *Conura* sp.5 (Hymenoptera: Chalcididae) had the lowest indices (nondominant, scattered, not frequent or accidental). *B. pandora* and *C. ventrispinosa* were considered super frequent corresponding to 52.42% of total parasitoids captured. *Conura* immaculata (Cresson), *Conura* sp.3, *Conura* sp.4, *Conura* sp.5, *Conura* sp.8, *Conura* sp.9 and *Conura* sp.10 (Hymenoptera: Chalcididae) occurred as accidental.

The indices shown that environments with similar diversity species between sites 2 and 3, with the population. Redominancy of *B. pandora*. The site 1, with native forest fragment, showed greater evenness index representing greater uniformity of individuals. The site 4 with adjacent pasture vegetation and *T. grandis* obtained the highest results for the species *B. pandora, C. ventrispinosa, C. nigrifrons* and *C. maculata* (Hymenoptera: Chalcididae) One observed that adjacent vegetation may influence the occurrence of Chalcididae [18].

5. Morphoclimatic domain - Araucaria Forest

This study aimed to know the entomological fauna of three floristic situations in the municipality of União da Vitória, identify the families of parasitoid hymenopteran, carry out a faunal analysis to characterize this population, comparing an area of native forest, a border area, and an area of agricultural cultivation.

A total of 625 individuals were collected, distributed into eight superfamilies and 15 families. The most abundant superfamily was the Ichneumonoidea with 52.32% of the total collected, followed by the Proctotrupoidea superfamily with 14.72% of the collections. Ceraphronoidea had the lowest number of families, 0.96%. The superfamily Chalcidoidea had the greatest diversity of families, five (Eulophidae, Pteromalidae, Encyrtidae, Chalcididae and Eupelmidae) (Figure 24), followed by Ichneumonoidea, Platygastroidea and Proctotrupoidea with two families.

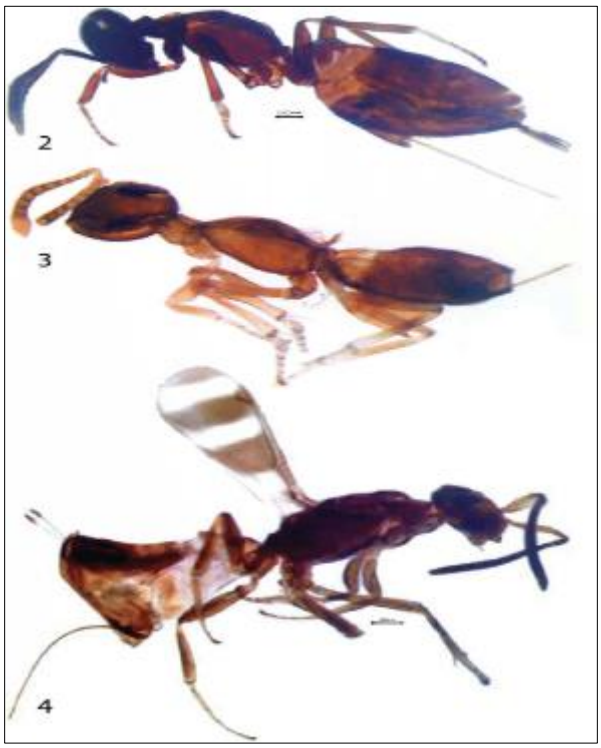

Figure 24 Specimens of the Eupelmidae Family; **Source**: https://www.researchgate.net/figure/Figures-2-4-Eupelmidae-2-Eupelmus-Macroneura-schmiedeknechti-Ruschka-3-Eupelmus_fig2_317392028.

The faunal analysis of the three areas collected shows that 13.3% of the families were very abundant, Ichneumonidae and Braconidae, 53.4% of the families were common, Bethylidae, Chalcididae, Diapriidae, Eulophidae, Figitidae, Monomachidae, Platygastridae and Scelionidae and 33 .3% of the families were dispersed Encyrtidae, Eupelmidae, Evaniidae, Megaspilidae and Pteromalidae; as for the constancy parameter, 40% of the families were constant, they were: Bethylidae, Braconidae, Diapriidae, Ichneumonidae, Scelionidae and Monomachidae; 26.7% were accessory, Chalcididae, Eulophidae, Figitidae and Platygastridae; and 33.3% accidental, Encyrtidae, Eupelmidae, Evaniidae, Megaspilidae and Pteromalidae; for dominance, 33.3% of the families were dominant, Bethylidae, Braconidae, Diapriidae, Ichneumonidae and Scelionidae and 66.7% of the families were non-dominant, Chalcididae, Eulophidae, Figitidae; Encyrtidae, Eupelmidae, Evaniidae, Megaspilidae, Monomachidae, Platygastridae and Pteromalidae.

As for the frequency, 13.3% of the families were very frequent, Ichneumonidae and Braconidae, 53.4% were frequent, Bethylidae, Chalcididae, Diapriidae, Eulophidae, Figitidae, Monomachidae, Platygastridae and Scelionidae and 33.3% uncommon, Encyrtidae, Eupelmidae, Evaniidae, Megaspilidae and Pteromalidae [19]

6. Morphoclimatic domain Cocais Forest

The objective of this study was to identify tephritid species, fruit hosts and associated parasitoids in the community in a rural community in the municipality of União (State of Piauí).

Of the 14 fruit species collected, only five hosts were found, observing the predominant infestation of *Anastrepha obliqua* macquart 1835 (Diptera: Tephritidae) on *Spondias mombin* L. (Anacardiaceae) and umbu (*Spondias tuberosa* Arr. Cam.) (Anacardiaceae) cajá. *Anastrepha zenildae* Zucchi, 1979 (Diptera: Tephritidae), in guava (*Psidium guajava* L.) (Myrtaceae). The cajazeira and the umbu tree were considered primary hosts of *Anastrepha obliqua* Macquart, 1835 (Diptera: Tephritidae) due to the high infestation obtained.

Three species of parasitoids emerged from the fruits: *Doryctobracon areolatus* (Szépligeti, 1911) (Hymenoptera: Braconidae), *Opius bellus* Gahan 1930 (Hymenoptera: Braconidae) and *Utetes anastrepha*e (Viereck, 1913) (Hymenoptera: Braconidae) (Figure 25) with high incidence of fruits *Spondias*. Six species of fruit flies were captured: *A. obliqua, A. zenildae* and *Anastrepha fraterculus* Wieldemann, 1830 (Diptera: Tephritidae) (Figure 25 a-h), *Anastrepha serpentina* Wieldemann, 1830 (Diptera: Tephritidae), *Anastrepha* sp.1 (Diptera: Tephritidae) and *Anastrepha* sp.2. (Diptera: Tephritidae) [20].

Figure 25 Parasitoid ovipositing (inside the fruit) in orange fruit fly larva;
Source: https://www.esalq.usp.br/visaoagricola/sites/default/files/va02-pragas05.pdf.

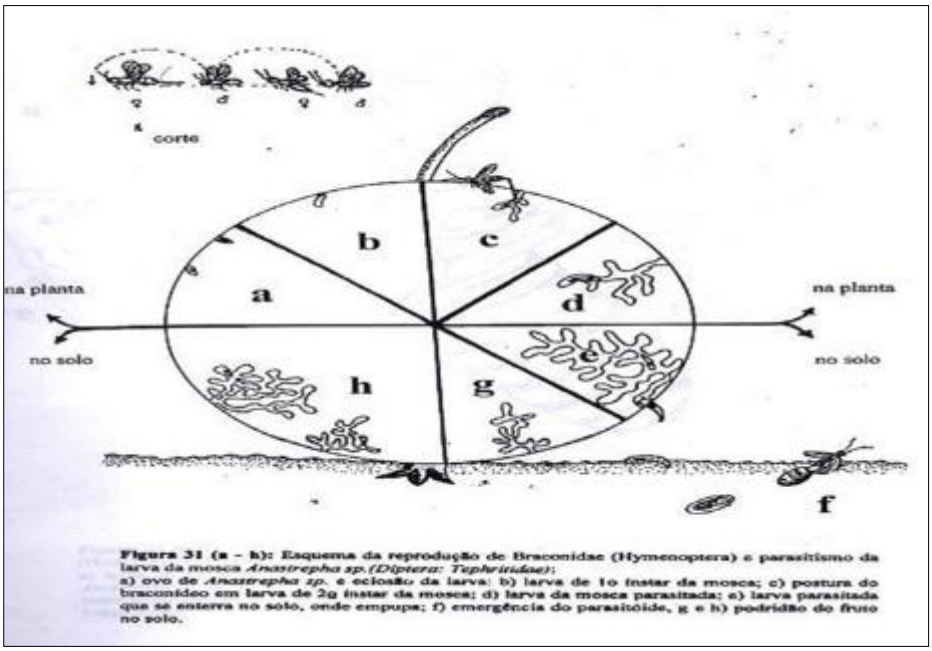

Figure 25 (a-h) Reproduction scheme of Braconidae (Hymenoptera) and parasitism of the fruit fly larvae *Anastrepha* sp. (Diptera: Tephritidae): a) egg of *Anastrepha* sp. And hatching of the larva: b) first instar larva of the fly; c) posture of the braconid in second instar larva of the fly; d) parasitized fly larva; e) parasitized larva that burrows into the ground, where it swells; f) parasitoid emergence, g and h) fruit rot in the soil; **Source**: Ioriatti MCS. Contribution to the Study of the Biology and Taxonomy of the Hymenoptera (Braconidae, Diapriidae, Eucoilidae and Pteromalidae) Parasitoids of

the Fruit Fly (Diptera, Tephritidae and Lonchaeidae).. 1995. Thesis (Doctorate in Ecology and Natural Resources) - Federal University of São Carlos (Figure 26 (a, b, c, d and e) Brazil.

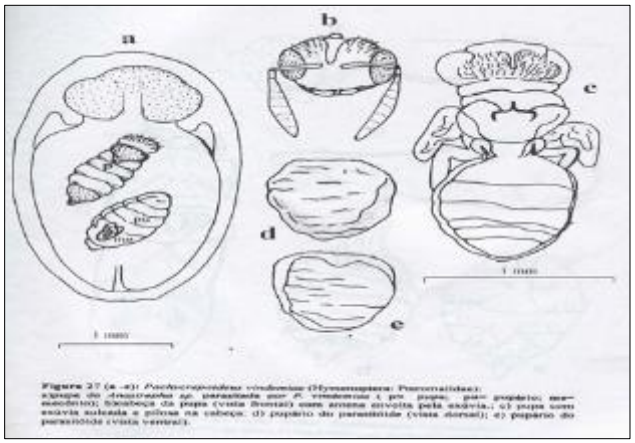

Figure 26 (a, b, c, d and e) *Pachycrepoideus vindemmiae* (Rondani, 1875) (Hymenoptera: Pteromalidae): a) *Anastrepha* sp. by *P. vindemmiae*; b) pupa head (front view) with an antenna surrounded by exuvia; c) pupa with furrowed and hairy exuvia on the head; d) parasitoid pupae (dorsal view); e) parasitoid pupae (ventral view); **Source**: Ioriatti MCS. Contribution to the Study of the Biology and Taxonomy of the Hymenoptera (Braconidae, Diapriidae, Eucoilidae and Pteromalidae) Parasitoids of the Fruit Fly (Diptera, Tephritidae and Lonchaeidae).. 1995. Thesis (Doctorate in Ecology and Natural Resources) - Federal University of São Carlos, Brazil.

7. Conclusion

Brazilian biomes and morphoclimatic domains are important not only as natural resources in our country but stand out as environments of great natural wealth on the planet. Brazil is one of the few countries in the world that hold the so-called biological megadiversity, that is, important ecosystems, still healthy. This biodiversity can offer unique opportunity for pest control in both Brazil and other countries, due to the identification of new organisms with potential to be used in biological control.

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