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(REVIEW ARTICLE)

Species of the Pteromalidae Family as a natural enemy of pest insects

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Abstract

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 Familia Pteromalidae (Insecta: Hymenoptera). The research was carried out in studies related to quantitative aspects taxonomic and conceptual aspects. A literature search was carried out containing articles published from 1964 to 2021. The mini review was prepared in Goiânia, Goiás, from September to October 2021, through the. The mini review was prepared in Goiânia, Goiás, from September to October 2021, through the Online Scientific Library (Scielo), internet, ResearchGate, Academia.edu, Frontiers, Publons, Qeios, Pubmed, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science, ERIC, Science Research.com, SEEK education, Periodicals CAPES, Google Academic, Bioline International, VADLO, Scopus, Web of Science, LILACS, Medline, LIS and Portal of Scientific Journals in Health Sciences.

Keywords: Biocontrol; Hosts; Taxonomy; Phylogeny; Insecta

1 Introduction

Pteromalidae is a family of wasps, mainly parasitoids, having more than 3500 species within about 580 genera worldwide. Among the different species, they are found in different environments and, consequently, they have varied eating habits and can be phytophagous or entomophagous: galleries, tenants, and different types of parasitoids ad predators (Figure 1A) [1,2].

Figure 1A Pteromalidae Family; (Source: https://www.biodiversity4all.org/taxa/125448-Pteromalidae)

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1.1 Characteristics

The larva is usually hymenopteriform although the last segment may be bilobed and the head and jaws are very large. Ectoparasite larvae have an open tracheal system, but in endoparasites, this system may be closed or even absent. Imago, on the other hand, has some diagnostic features, but it is not exclusive to the group, and they are cited 5 tarsomeres on the fore and hind legs (one of the subfamilies has 4 tarsomeres on the second pair of legs) (Figure 1B).

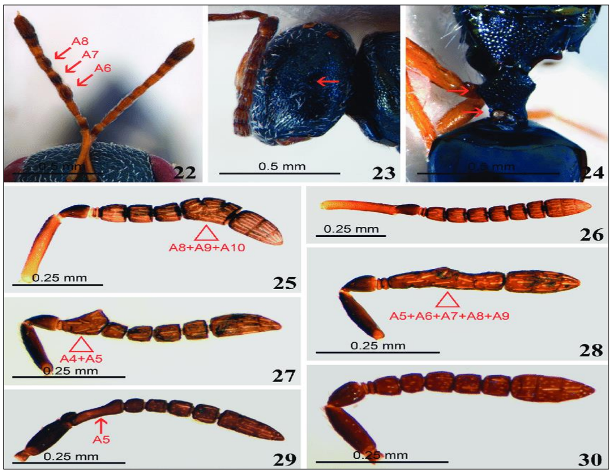


Figure 1B Teratological Pteromalidae. 22, 23, *Norbanus africanus* Subba Rao, 1973, females: 22. Teratological (left) and normal (right) antennae, 23. Cyclopy; 24, *Sphegigaster* sp., petiole asymmetry; 25, 26, *Pteromalus* sp., female: 25. Teratological antenna, 26. Normal antenna; 27, 28, *Systasis parvula* Thomson, 1876, female, teratological antennae; 29, 30, *Schrenkiella parvula* (Schrenk), male: 29. Teratological antenna, 30. normal antenna; (Source: https://www.researchgate.net/figure/Figures-22-30-Teratological-Pteromalidae-22-23-Norbanus-africanus-females-22_fig1_262485262)

Body typically 1–7 mm, reaching 48 mm, often metallic; antennas with 8 to 13 articles (3 rings); anterior wing marginal vein several times longer than large, post marginal and stigmal veins often well developed and distinct speculum. Pteromalidae with forewings without closed cells (Figure 1C) [3,4].

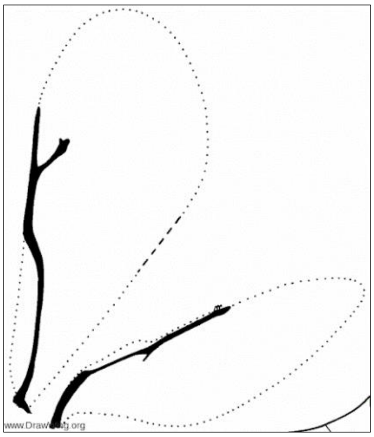


Figure 1C Wings of Pteromalidae from; (Source: Goulet and Huber (1993))

1.2 Ecology

They present a variety of lifestyles. Some are solitary and others gregarious, may be external parasitoids (ectoparasitoids) or internal (endoparasitoids); that does not kill the host immediately (koinobiontes) or paralyze the host, so it dies (idiobiontes). Some are hyperparasitoid, the bone that they parasitize to other parasitoids. There are only a few predators that kill their prey (Figure 1D) [4].

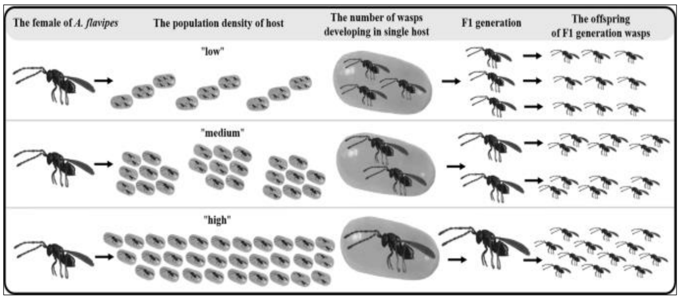


Figure 1D The number of wasps developing in one host egg, their adult body size and future fertility are influenced by the host population density of the host. Each female has 34 offspring, but the size of their offspring depends on the number of individuals developed in one host. Wasps lay a higher number of eggs into one host egg and therefore produce smaller offspring if the population density of hosts is "low" compared "medium" and "high" population densities of hosts. The body size of the F1 generation female wasps determines the number of developed offspring. The number of offspring per host egg is illustrative because it does not reflect the real number of developed offspring; (Source: https://www.nature.com/articles/s41598-019-42503-4)

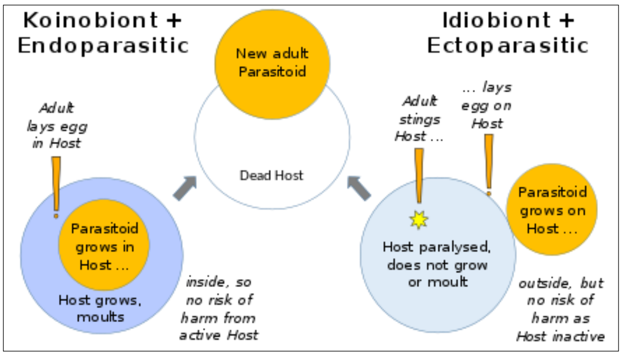


Figure 1E Two strategies found among parasitoidal wasps: Ectoparasites are usually idiobiont, endoparasites koinobiont. Parasitoids can also be divided according to their effect on their hosts. Idiobionts prevent further development of the host after initially immobilizing it, while koinobionts allow the host to continue its development while they are feeding upon it; and again, both types are seen in parasitoidal wasps. Most ectoparasitoid wasps are idiobiont, as the host could damage or dislodge the external parasitoid if allowed to move or moult. Most endoparasitoid wasps are koinobionts, giving them the advantage of a host that continues to grow larger and remains able to avoid predators; (Source: https://en.wikipedia.org/wiki/Parasitoid_wasp)

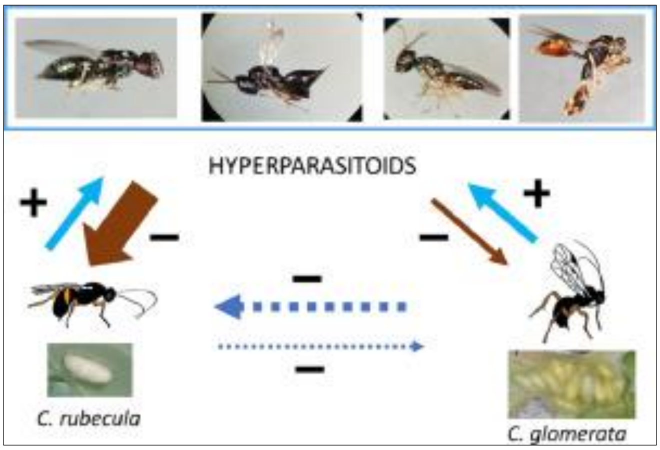
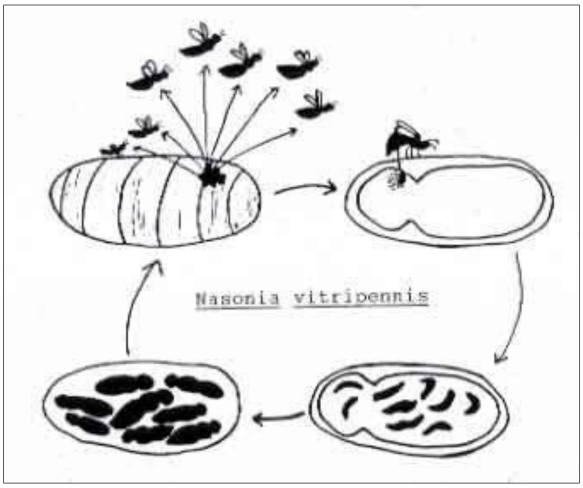


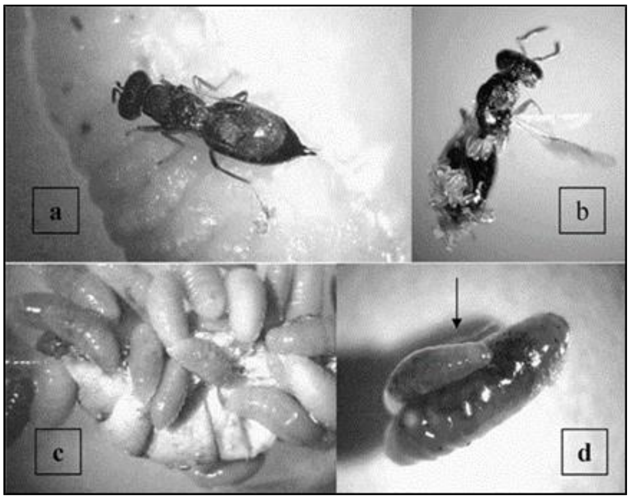
Figure 1F Hyperparasitoids are frequently implicated in the failure of parasitoid biological control agents to establish and provide control of insect pests. The outcome of competition among two or more parasitoid species may be altered if the parasitoids are differentially attacked by the same hyperparasitoids. A reliable assessment of the hyperparasitoid community is needed to understand how top-down trophic interactions influence the effectiveness of introduced parasitoids; (Source: https://www.sciencedirect.com/science/article/abs/pii/S1439179120300529)

The Pteromalidae family (Hymenoptera, Chalcidoidea) includes many parasitoid species, many of which are important for the biological control of synanthropic muscoids. A majority, idiobiont, and many develop as ectoparasitoids in larvae or pupas of Diptera, Coleoptera, Hymenoptera, Lepidoptera and Siphonaptera (Figure I E, F and G) [4].



A

Figure 1G A The life cycle of *Nasonia vitripennis* (Walker, 1836); (drawing by Bethia King). The life cycle of *Melittobia* is the same, though individuals at all stages are smaller. Gregarious parasitoid and endoparasitoids



B

Figure 1G B Parasitoids gregarious (a) *Dibrachys pelos* Grissell 1974 (Hymenoptera: Pteromalidae) female on prepupa of *Sceliphron caementarium* Drury, 1773 (Hymenoptera, Sphecidae); body length of adult female *D. pelos* = 3 mm; (b) Eggs of *Montipora digitata* (Dana, 1846) · Scleractinia (Order) · Acroporidae (Family) · *Montipora* (Genus) on abdomen of newly eclosed adult *D. pelos*; (c) Gregarious larvae of *D. pelos* feeding on *Anthrax* sp. (Diptera: Bombyliidae); (d) Larva of *M. digitata* (arrow) feeding on larva of *D. pelos*. The life cycle of *N vitripennis*; (drawing by Bethia King). The life cycle of *Melittobia* is the same, though individuals at all stages are smaller. Gregarious parasitoid and ectoparasitoids; (Source: https://www.researchgate.net/figure/The-life-cycle-of-Nasonia-vitripennis-drawing-by-Bethia-King-The-life-cycle-of_fig4_242121220)

It must be proved that the individuals found in the plant species were also phytophagic by type, as they presented a gall morphology and only one species of galling insect. Its preference for this host can be attributed to the presence of calcium carbonate secretion that other species of *Tabebuia secrete* (Ridley) (Bignoniaceae) *i*n its leaves (Figure 1G) [5,6,7].

Figure 1G Ectoparasitoids; (Source: https://allyouneedisbiology.wordpress.com/tag/parasitoid-benefits/)

Galls are atypical two plant tissue transformations, hypertrophy and/or hyperplasia. They can be induced by various organisms, such as viruses, bacteria, fungi, nematoids, mites and mainly by insects, as they are known as entomogenic galls, but these galls can occur in various parts of the plant, they are most common with leaves and bouquets (Figure 1H) [5,6,7].

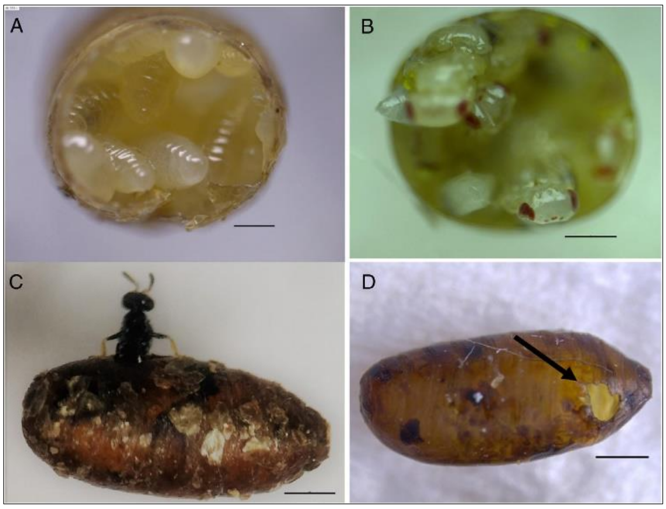


Figure 1H Endoparasitoids; (Source: https://www.scielo.br/j/rbent/a/K3GqqMyQ8NbBBjYPC8qKxpF/?lang=en)

1.3 Hosts

Generally, this family has a wide host range. Most species are gregarious ectoparasitoids of larvae and pupae of Lepidoptera and Coleoptera, but several species attack larvae and pupae of Diptera as well. Some are predaceous on eggs of Coccidae. There are no phytophagous species. Considerable importance has been placed on pteromalids for biological control of Lepidoptera, Coleoptera and synanthropic Diptera. A few species have also been used for the biological control of Coccidae (Figure I, J and L) [8,9,10].

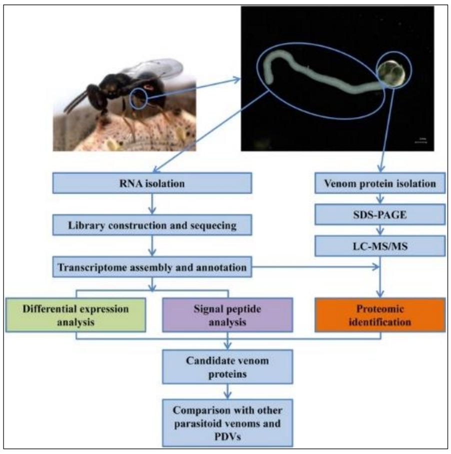


Figure 1H Schematic representation of combined proteomic and transcriptomic analyses to identify putative venom proteins in *Pteromalus puparum* L. 1758 (Hymenoptera: Pteromalidae); (Source: https://www.nature.com/articles/srep19604)

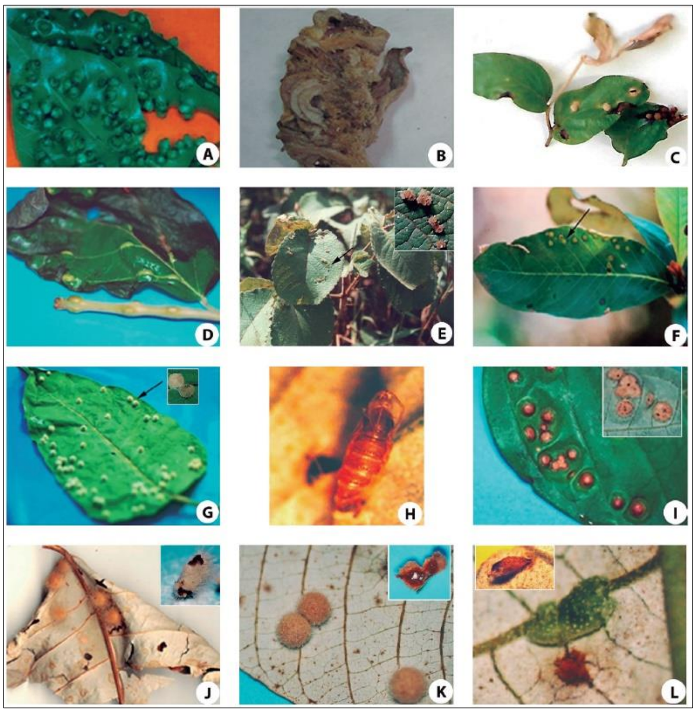


Figure 1I Gall morphotypes are vegetal structures produced by an abnormal increase of plant cells, tissues or organs in response to specific stimulation caused by an inductor agent, such as a virus, bacteria, nematodes or insects; (Source: https://www.scielo.br/j/paz/a/ndXDWLYv6hP8x5nCP6Yzh5C/?lang=en)

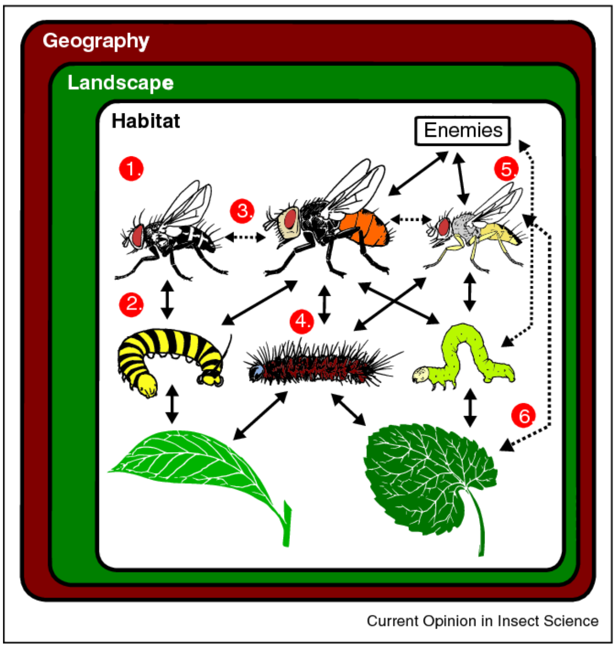


Figure 1J Most studies; however, are focused primarily on parasitic wasps, despite the thousands of other insect parasitoids distributed across many lineages. Although questions in parasitoid community ecology are much the same for different groups, answers to these questions may not be due to differing biological traits. The ecology of non-hymenopteran ('NH') parasitoid communities is poorly known, but recent work indicates that habitat; (Source: https://www.semanticscholar.org/paper/Community-ecology-of-the-%27other%27-parasitoids.-Stireman/8e416dcff3bb698a11877eca7d45c002ede74661)

1.4 Geographical distribution

The five described species occur in geographic isolation in the Nearctic and Neotropical regions, except two species which are sympatric in the western Nearctic. The suspected ancestor of this apparent clade is widely distributed in Europe, Africa, North America, and portions of the Pacific area but it has not been found in the Neotropics. There are no known clinal patterns. The genus has not been reported from Asia and is poorly represented in equatorial regions [11,12,13].

The only known South American occurs as three or more separate populations. One population from coastal Peru is solitary, whereas the others show various degrees of gregarious oviposition and development (two or more eggs laid at one insertion). One of the gregarious populations from central Chile oviposits more than one egg in 60% of the hosts it attacks, with subsequent successful gregarious development. The Chilean population compensates for a lower host-searching capacity with the gregarious behavior, which results in a greater number of progenies per host [11,12,13].

1.5 Habitat

They parasitize pupae of Diptera, Coleoptera, Hymenoptera, Lepidoptera and Siphonaptera. Many species attack hosts that are not already vegetative, such as wood perforator's, leaf furators and gall formers. Fertilization varies in each species, but one female can produce about 700 eggs [12,13,14].

Adult Habits. The time between emergence of adults and oviposition is short. Females of *Nasonia vitripennis* (Walker, 1836) deposit eggs within three hours of emergence, and *Habrocytus cerealellae* Ashmead, 1902 (Pteromalidae) does so the following day. Two to three days are required by *Dibrachoides dynastes* Foerst, 1841 (Pteromalidae). Lays its first eggs 7-8 days after adult emergence. Most prevalent in or near accumulated decaying organic material deposited by humans and livestock, where they parasitize host Diptera that also breed selectively in this habitat. Therefore, they fit the endophilous synanthropic category and their existence depends largely on herdsmen [12,13,14].

1.6 Taxonomy

Class: Insecta, Order: Hymenoptera, Suborder: Apocrite, Superfamily: Chalcidoidea, Family: Pteromalidae Dalman, 1820 (Figures 2, 3, 4 and 5).

1.6.1 Subfamilies

Asaphinae - Austrosystasinae - Austroterobiinae - Ceinae - Cerocephalinae - Chromeurytominae - Cleonyminae - Coelocybinae - Colotrechninae - Cratominae - Diparinae - Ditropinotellinae - Elatoidinae - Epichrysomallinae - Erotolepsiinae - Eunotinae - Eutrichosomatinae - Herbertiinae - Keiraninae - Leptofoeninae - Louriciinae - Macromesinae - Miscogasterinae - Nefoeninae - Neodiparinae - Ormocerinae - Otitesellinae - Panstenoninae – Parasaphodinae - Pireninae - Pteromalinae - Spalangiinae - Storeyinae - Sycoecinae - Sycoryctinae [12,13,14].

Figure 2 *Leptofoenus stephanoides* (Roman 1920) Male; (Source: https://www.google.com/search?q=Pteromalus+puparum&oq=Pteromalus+puparum&aqs=chrome.69i57j46i19.1467j0j7&sourceid=chrome&ie=UTF-8)

Figure 3 *Nasonia vitripennis* (Walker, 1836) (Pteromalidae: Spalanginae); (Source: https://www.google.com/search?q=Pteromalus+puparum&oq=Pteromalus+puparum&aqs=chrome.69i57j46i19.1467j0j7&sourceid=chrome&ie=UTF-8)

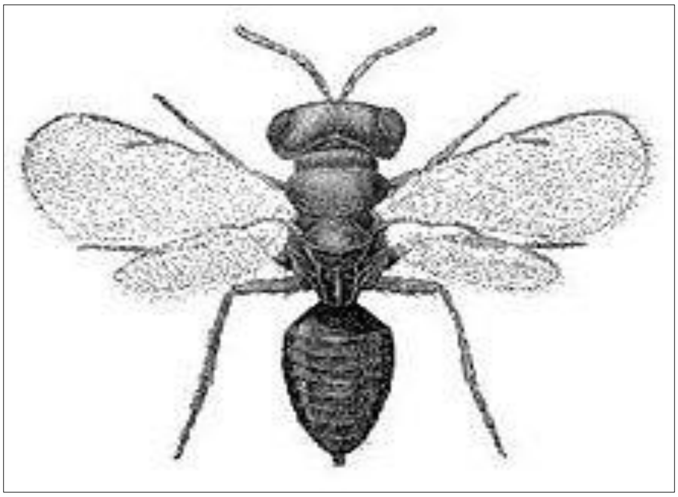


Figure 4 *Pteromalus puparum* (L., 1758); (Source: https://www.google.com/search?q=Pteromalus+puparum&oq=Pteromalus+puparum&aqs=chrome.69i57j46i19.1467j0j7&sourceid=chrome&ie=UTF-8)

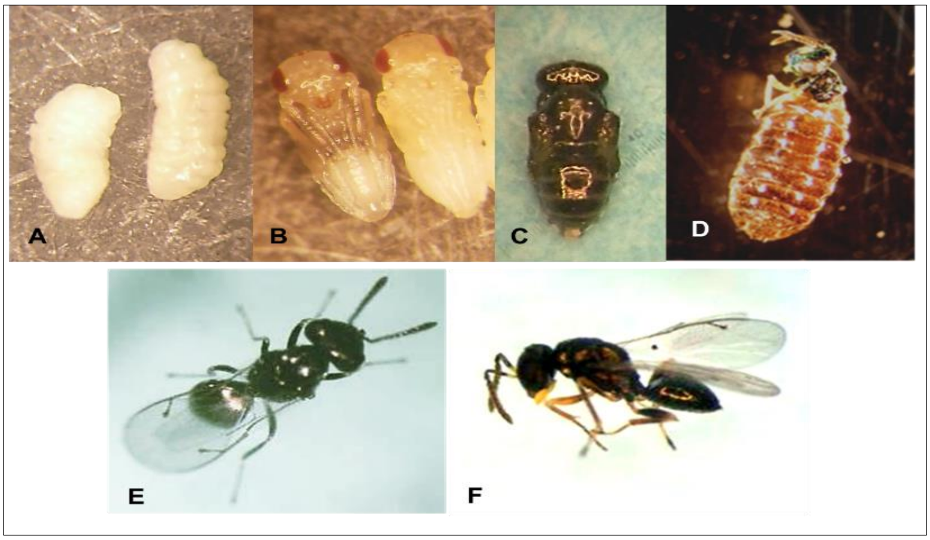


Figure 5 The development stages of *Halticoptera arduine* (Walker, 1843 (Hymenoptera: Pteromalidae): (A) larva, (B and C) pupae, (D) adult emerging from fly´s puparium, (E) female adult, and (F) male adult; (Source: Photos: Courtesy of CIP)

1.7 Reproduce

1.7.1 Egg

Eggs are 0.4 x 0.15 mm in size and are hymenopteriform; a caudal extension with three hooks (like an anchor) allows the egg to adhere to the internal organs of the host. Corium is transparent and smooth, pale yellow. [14,15].

1.7.2 Larva

Four larval instars are described. First instar is hymenopteriform (0.35 x 0.15 mm) with 13 segments, including the conical cephalic capsule with triangular mandibles that are the most sclerotic part of the body. Second (1.93 x 1.04 mm) and third (2.29 x 1.30 mm) instars are vermiform. Fourth instar is typically hymenopteriform with 13 segments, showing the oral region in the cephalic segment (2.49 x 1.34 mm) [14,15].

1.7.3 Pupa

Pupation occurs within the host puparium. Pupa is hymenopteriform, sculpted, bright white, and 1.51 mm long

1.7.4 Adult

Tarsi are 5-segmented; antennae have six funicular segments and a complete notaulus. Petiole is distinct though may be small. Median area of propodeum is virtually smooth. Parapsidal sutures are fully well marked in entirety. Pronotal collar is long, slightly margined. The species presents sexual dimorphism. *Female*: Body is completely dark with pale greenish, golden, and purple reflexes and dark scape antennae. Maxillary palpi and stipites are dark. Body is 1.32–1.68 mm long. *Male*: Body has purple and green reflections; stipites are quite apparent and yellow. Maxillary palpi are enlarged and yellow, and scape has a yellow basal portion. Body is 1.32–1.58 mm long (Figures 6A, 6B, 6C, 7, 8, 9 and 10) [14,15].

1.8 Life cycle

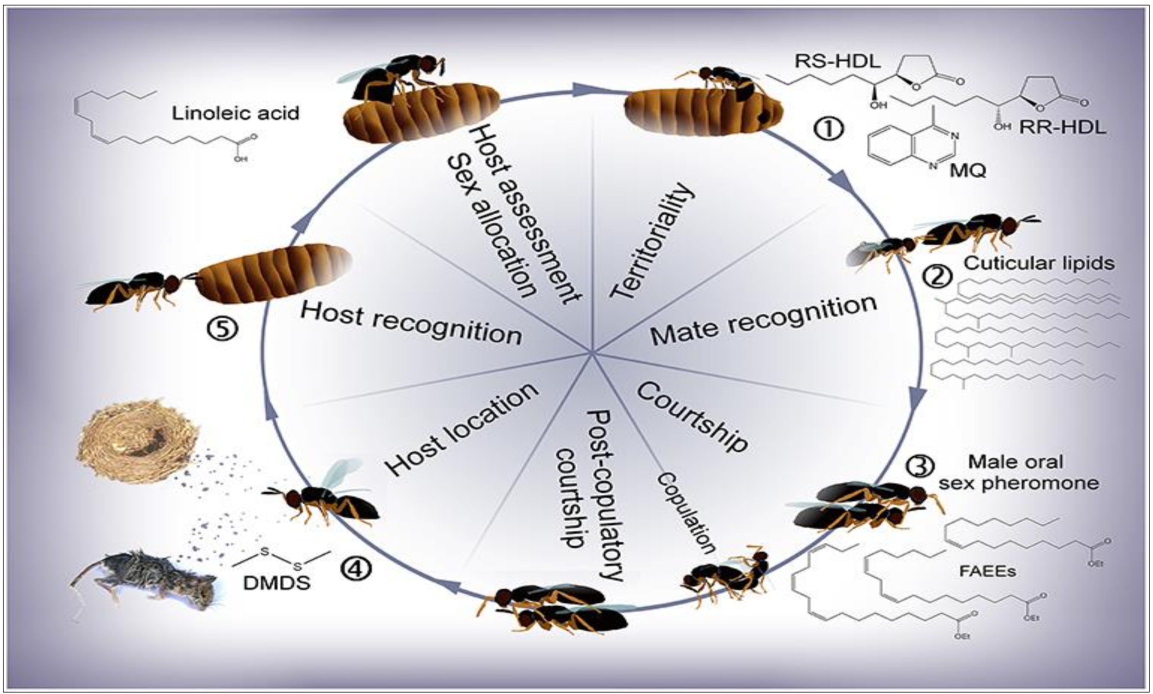


Figure 6A Life cycle of *Nasonia* with emphasis on the different stages at which semi chemicals are involved. (1) Males apply an abdominal sex pheromone to the natal host and its surroundings to attract and arrest emerging females. (2) Males recognize females based on the females' cuticular hydrocarbons (CHCs, of *Nasonia vitripennis* (Walker, 1836) or cuticular lipids (CLs, = cuticular hydrocarbons + polar lipids, *Nasonia giraulti* Darling, 1990. (3) During courtship, a male oral sex pheromone is transferred to the female's antennae, females discriminate between conspecific and heterospecific mating partners and post-copulatory courtship induces a switch in the females' receptivity. (4) Females find new hosts based on olfactory cues. (5) Chemical stimuli are most likely involved during host recognition, host assessment and sex allocation (according to local mate competition theory). RR-HDL, (4R, 5R) -5-hydroxy-4-decanolide; RS-HDL, (4R, 5S) -5-hydroxy-4-decanolide; MQ, 4-methylquinazoline; FAEEs, fatty acid ethyl esters; DMDS, dimethyldisulphide; (Source: Mair MM, Ruther J. Chemical Ecology of the Parasitoid Wasp Genus *Nasonia* (Hymenoptera, Pteromalidae). Frontiers Ecology and Evolution. 2019; 7(184): 1-19)

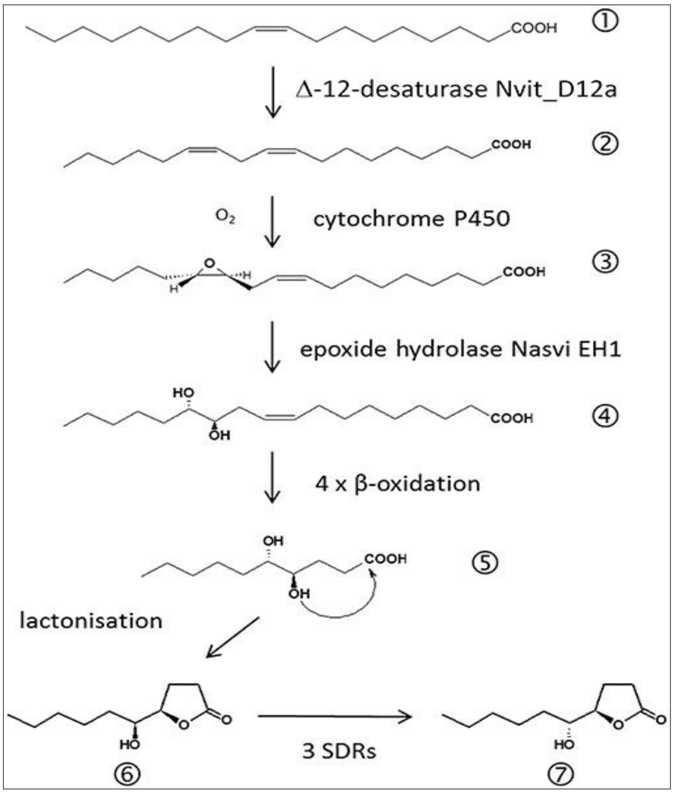


Figure 6B Biosynthetic pathway of the major *Nasonia* male abdominal sex pheromone components. (1) oleic acid, (2) linoleic acid, (3) 12,13-epoxy-(9Z)-octadecenoic acid, (4) 12,13-dihydroxy-(9Z)-octadecenoic acid, (5) 4,5 - dihydroxydecanoic acid, (6) (4R,5S)-5-hydroxy-4-decanolide (RS-HDL), (7) (4R,5R)-5-hydroxy-4-decanolide (RR-HDL); (Source: https://www.frontiersin.org/articles/10.3389/fevo.2019.00184/full)

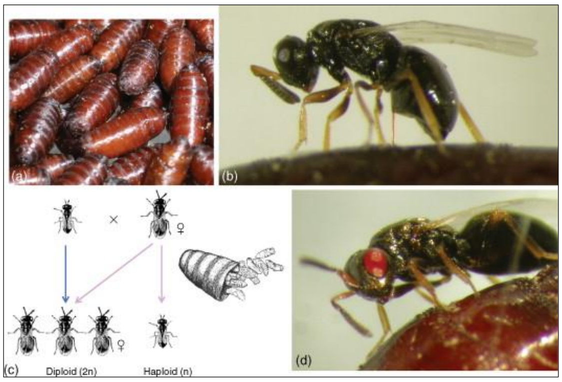


Figure 6C Some aspects of *Nasonia* biology. (a) Blowfly pupae are the host for this parasitoid wasp. (b) The female *Nasonia* laying eggs on a host: females choose hosts depending on the host species, its size, and whether or not other females have already parasitized the host. (c) As with all Hymenoptera, Nasonia are haplodiploid, with females being diploid (2n), carrying chromosomes only from their mother (pink arrow) and father (blue arrow), while males are haploid (n), carrying chromosomes only from their mother (pink arrow). Inset: Nasonia is gregarious, with multiple wasp pupae developing on one fly pupa, within the host puparium. (d) There are a number of visible mutant markers available, derived from early studies of mutation in Nasonia; shown here is the red-eye mutant STDR, often used in studies of sex ratio in *Nasonia*. Photographs by David Shuker and Stuart West; (Source: Whiting AR. The biology of the parasitic wasp *Nasonia vitripennis* (Walker, 1836). Quarterly Review of Biology. 1967; 42: 333–406, used with permission from the University of Chicago Press)

1.9 Phenology

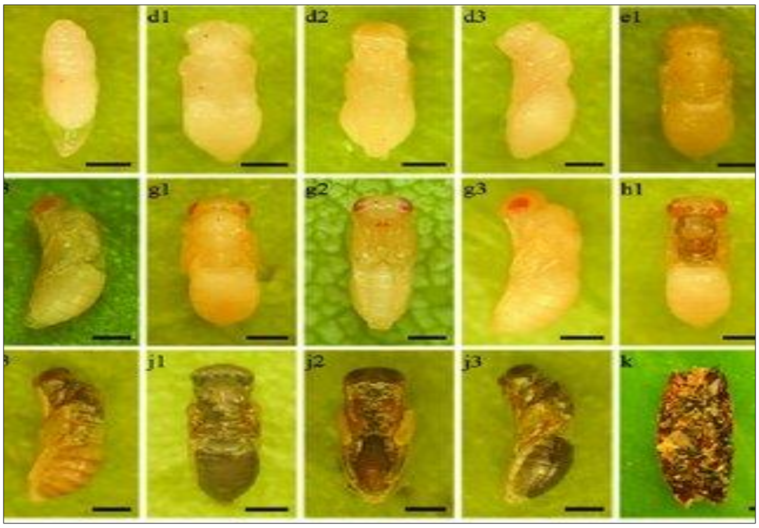


Figure 7 Developmental characteristics of *Nasonia vitripennis* (Walker, 1836) on *Boettcherisca peregrina* Robineau-Desvoidy, 1830 (Diptera: Sarcophagidae) host. (a) Newly hatched larva are indicated by black arrow on the surface of fly pupae (puparium opened), and white arrow indicates the necrotic spots; (b) larva with fat body; (c) early prepupa; (d1) dorsal view of white pupa; (d2) ventral view of white pupa; (d3) lateral view of white pupa; (e1) dorsal view of yellow pupa; (e2) ventral view of yellow pupa; (e3) lateral view of yellow pupa; (f1) dorsal view of pupa with pink eyes; (f2) ventral view of pupa with pink eyes; (f3) lateral view of pupa with pink eyes; (g1) dorsal view of pupa with red eyes; (g2) ventral view of pupa with red eyes; (g3) lateral view of pupa with red eyes; (h1) dorsal view of pupa with pigmented head and thorax; (h2) ventral view of pupa with pigmented head and thorax; (h3) lateral view of pupa with pigmented head and thorax; (i1) dorsal view of pupa with striped abdomen; (i2) ventral view of striped abdomen; (i3) lateral view of pupa with striped abdomen; (j1) dorsal view of pupa with all-black abdomen; (j2) ventral view of all-black abdomen; (j3) lateral view of pupa with all-black abdomen; (k) newly exuviating adult within host puparium; (l1) host puparium with wasp exit holes (arrow); (l2) adult emergence from host puparium, white arrow indicates the male wasp, and black arrow indicates the female wasp. Scale bars are variable in length and represent 0.5 mm; (Source:https://www.researchgate.net/publication/328699418_Development_of_Nasonia_vitripennis_Hymenoptera_Pteromalidae_at_Constant_Temperatures_in_China/link/5e37a98992851c7f7f17b81e/download)

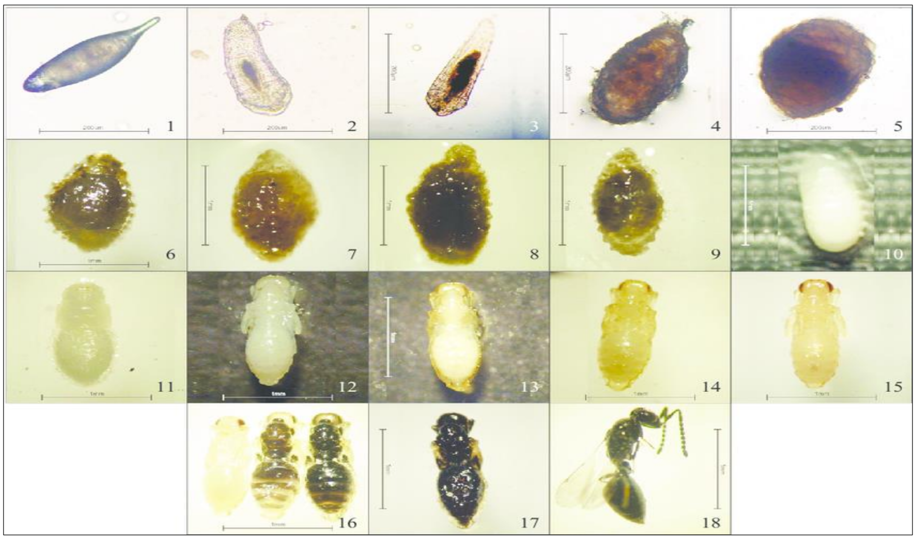


Figure 8 Phenology of *Spalangia endius* Walker1938, (Hymenoptera, Pteromalidae), in pupae of *Musca domestica* Linnaeus, 1758, (Diptera, Muscidae) at 26°C, relative humidity 70% and photo phase of 12 hours. (Fig. 1) egg; (Figs. 2–9) larval period; (Fig. 10) prepupa; (Figs. 11–17) o pupal period, and (Fig. 18) adult. Scale 200 μm (Figs. 1–5) and scale 1 mm (Figs. 6–18); (Source: https://www.researchgate.net/figure/Figures-1-18-Phenology-of-Spalangia-endius-Walker1938-Hymenoptera-Pteromalidae-in_fig1_259557157)

1.10 Biological control

Natural biological suppression of the house fly results primarily from the actions of certain chalcidoid wasps (Hymenoptera: Pteromalidae), of which many species have been associated with house fly around the world. Among the more important are *Muscidifurax* and *Spalangia* spp. Ichneumonids and other parasitoids, as well as some predatory insects (especially histerids [Coleoptera: Histeridae] and staphylinids [Coleoptera: Staphylinidae]), also contribute to fly mortality, but under optimal fly breeding conditions the house fly quickly builds to high numbers. The more important in poultry facilities are the wasps *Muscidifurax raptor* Girault & Sanders, 1910 and *Spalangia cameroni* Perkins, 1910. Leaving a layer of old manure in the pits when manure is removed might enhance or stabilize the suppression of the house flies' densities by parasitoids and predators [16,17,18,19,20].

Figure 9 House fly puparia, each with a hole from which a single wasp emerged after feeding on the pupa. Feeding occurs in the larval stage, and the wasp eventually emerges as an adult; (Source: https://entnemdept.ufl.edu/creatures/urban/flies/house_fly.htm Photograph by USDA)

Figure 10 *Muscidifurax raptor* Girault & Sanders, 1910 wasp on a fly puparium. Once the female chooses a suitable puparium host, she lays a single egg in it. The egg hatches, and the wasp larva feeds on the fly pupa; (Source: https://entnemdept.ufl.edu/creatures/urban/flies/house_fly.htm Photograph by USDA)

Objective

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 Familia Pteromalidae (Insecta: Hymenoptera).

2 Methods

The research was carried out in paper related to quantitative aspects taxonomic and conceptual aspects. A literature search was carried out containing articles published from 1993 to 2021. The mini review was prepared in Goiânia, Goiás, from September to October 2021.

The mini-review was prepared in Goiânia, Goiás, from September to October 2021, through the Online Scientific Library (Scielo), internet, Pubmed, ResearchGate, Academia.edu, Frontiers, Biological Abstract, Publons, Qeios and Portal of Scientific Journals in Health Sciences, and Pubmed.

Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science, ERIC, Science Research.com, SEEK education, Periodicals CAPES, Google Academic, Bioline International, VADLO, Scopus, and Web of Science, LILACS, Medline, LIS and Portal of Scientific Journals in Health Sciences.

3 Studies carried out

3.1 Study 1

The objective of this work is to report the first occurrence of *Spalangia cameroni* Perkins 1910 parasitizing *Ornidia obesa* Fabricius, 1775 (Diptera: Syrphidae) in Brazil.

In the period from August to December 2007, there were 21 specimens of *O. obesa*, two which emerged, two specimens of the parasitoid *S. cameroni*. The percentage of parasitism was 9.5% (Figure 11) [21].

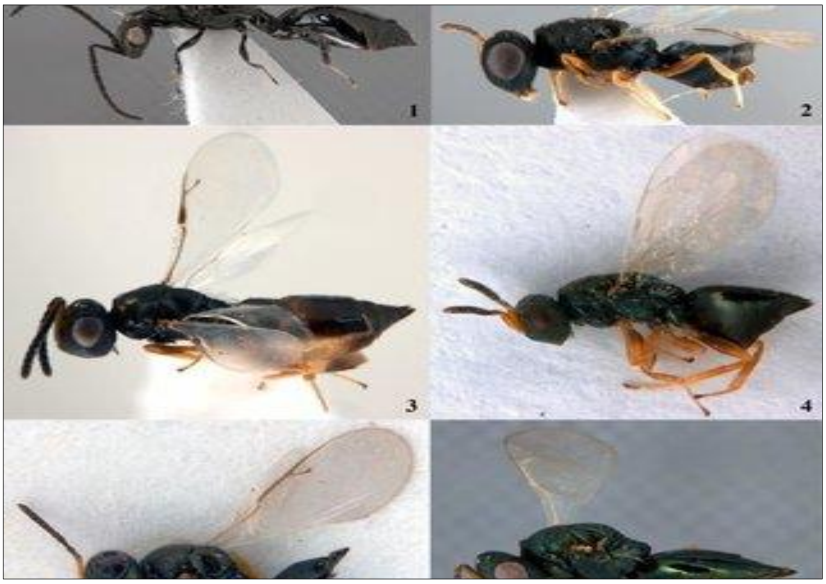


Figure 11 Pteromalid parasitoids of synanthropic flies. 1. *Spalangia nigroaenea* Curtis, 1839, ♂; 2. *Pachycrepoideus* sp., ♀; 3. *Muscidifurax* sp., ♀; 4. *Nasonia vitripennis* (Walker, 1836), ♀; 5. *Urolepis* sp., ♀; 6. *Trichomalopsis* sp., ♀ ; (Source: https://www.researchgate.net/figure/Figures-1-6-Pteromalid-parasitoids-of-synanthropic-flies-1-Spalangia-nigroaenea-2_fig1_282359294)

No Brazil, *S. cameroni* was found parasitizing *Chrysomya putoria* (Wiedemann, 1819) (Diptera: Calliphoridae), *Fannia trimaculata* (Stein, 1898) (Diptera: Fanniidae) *Musca domestica* L. 1758 (Diptera: Muscidae), *Muscina stabulans* (Fallèn, 1817) (Diptera: Muscidae), *Stomoxys calcitrans* (L., 1758) in feces of chicken in Goiás, *O. obesa* was found parasitized as *Pachycrepoideus vindemmiae* (Rondani 1875) (Hymenoptera) also in feces of chicken. Parasitoid microhymenopterans of the Pteromalidae family are naturally collected, emerging from dipteran pupae that proliferate in the manure of birds and some species can be used as biological controllers [21].

3.2 Study 2

Thus, or objective of this work was to verify the occurrence and characterization of entomogenic galls in dry and wet seasons in an ecotone area, between the Cerrado-Pantanal biomes, Aquidauana, Mato Grosso do Sul [22].

During the samples recorded three species of plants parasitized by insect galls, were: *Duguetia furfuracea* (Annonaceae family), *Tabebuia chrysotricha* Mart. Ex. DC.*)* Standl. (Bignoniaceae family) and *Eugenia pitanga* (Myrtaceae family). Among the species of gallers were insects observed are the orders Coleoptera, Hymenoptera and Diptera. Distributed in novel families (Figures 12 and 13). (Torymidae, Braconidae, Cynipidae, Mymaridae, Scelionidae, Cynipidae, Pteromalidae, Scelionidae, Braconidae, Eurytomidae, Mymaridae, Cecidomyiidae, Cecadellidae, Pteromalidae, Eurytomidae and Cecadellidae) and 18 morphospecies (Figure 12 and 13) [22].

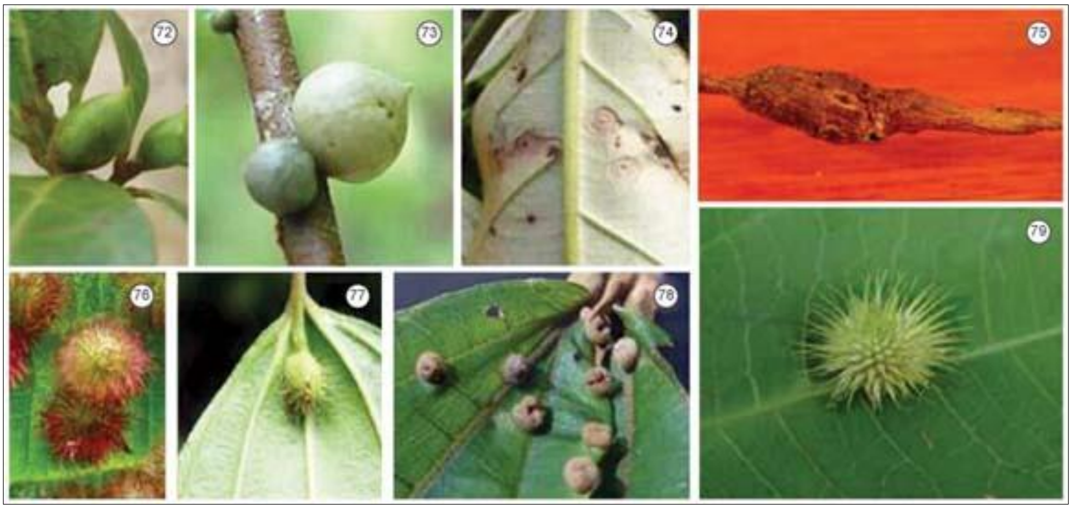


Figure 12 Gall-causing Pteromalidae; (Source: https://www.scielo.br/j/bn/a/sKV3QtMh7rDpscZPyf5HDrn/?lang=pt)

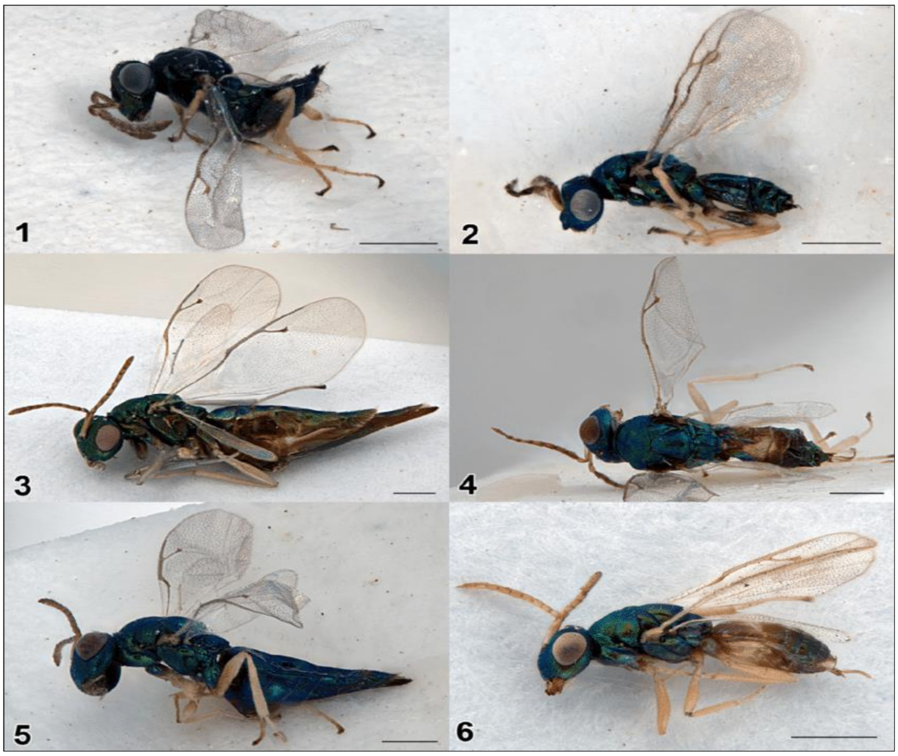


Figure 13 Species of Pteromalidae associated with plant galls: 1. *Gastrancistrus ephedrae* Dzhanokmen, 1994, female; 2. *G. ephedrae*, male; 3. *Pteromalus cyniphidis*, (Linnaeus, 1758), female; 4. *P. cyniphidis*, male; 5. *Pteromalus dolichurus*, (Thomson, 1878), female; 6. *P. dolichurus*, male. Scale bar: 0.5 m; (Source: https://www.researchgate.net/figure/Figures-1-6-Species-of-Pteromalidae-associated-with-plant-galls-1-Gastrancistrus_fig1_285413940)

Alternatively, shrub *Duguetia furfuracea* (Annonaceae), popularly known as field Pindauva, was or that shows a greater abundance of galls and wealth of insects. The morphology of the gall was green in color and in a globoid format, with a total of 241 harvested and measured galls, showing a mean (± standard deviation) of 4.7 ± 2.39 mm in length and an average of 4.9 ± 1.93 mm compression. It is in a large part in the ad axial region (upper part) of the leaves and does not appear to be pubescent. Their loculi will vary from two to seven chambers and from one to 14 orifices of outlet. No shrub *D. furfuracea* was quantified a total of fifty-two insects [22].

No shrub *D. furfuracea* was quantified a total of fifty-two insects. The predominant insects of the Cynipini tribe belonging to the Cynipidae family of the Hymenoptera order. Most of the Cynipini are inducers of galls and parasitic Fagaceae and Nothofagaceae. A second plant species with the presence of galls was a *Handroanthus chrysotrichus* (Mart. ex DC.), popularly known as Ipê Amarelo [22].

They have been observed in *Tabebuia chrysotricha* (Mart ex DC.) (Bignoniaceae) a total of 92 galls collected. There is a greater incidence of galls on the abaxial surface (lower part) of the sheet and will present a conical format of green coloring with an average of 5.0 ± 1.37 mm in length and 2.1 ± 0.5 mm in compression. The *T. chrysotricha* species obtained a total of thirty insects of the Galler type, with a predominance of the Hymenoptera, Pteromalidae family and Colotrechninae subfamily [22].

3.3 Study 3

The aim of this study was to verify the species of parasitoids of the family Pteromalidae associated with pupae of muscoid dipterans deposited in cattle feces in the municipality of Panamá, Goiás.

From May to December 2003, six species of parasitoids of the Pteromalidae family were collected from 293 Diptera pupae. Of the total, 43 were parasitized, each by a single parasitoid. Five specimens of *Pachycrepoideus vindemmiae* (Rondani, 1875), four specimens of *Spalangia cameroni* Perkins, 1910, seven specimens of *Spalangia drosophilae* Ashmead, 1885, two specimens of *Spalangia endius* Walker, 1889, seven specimens of *Spalangia nigra* Latrielle, 1830 and 18 specimens of *Spalangia nigroaenea* Curtis, 1839 were collected. The total occurrence of parasitism observed was 14.7% (43/293) [23].

The occurrences of parasitism of *P. vindemmiae, S. cameroni, S. drosophilae, S. endius, S. nigra* and *S nigroaenea* were 1.7% (5/293), 1.4% (4/293), 2 .4% (7/293), 0.7% (2/293), 2.4% (7/293) and 6.1% (18/293), respectively.

Spalangia nigroaenea was the most collected species with 41.9% (18/43) and was also the most frequent in pupae of *Brontaea quadristigma* (Thomson, 1869) (Diptera: Muscidae), with 16.1% (Figure 14) [23].

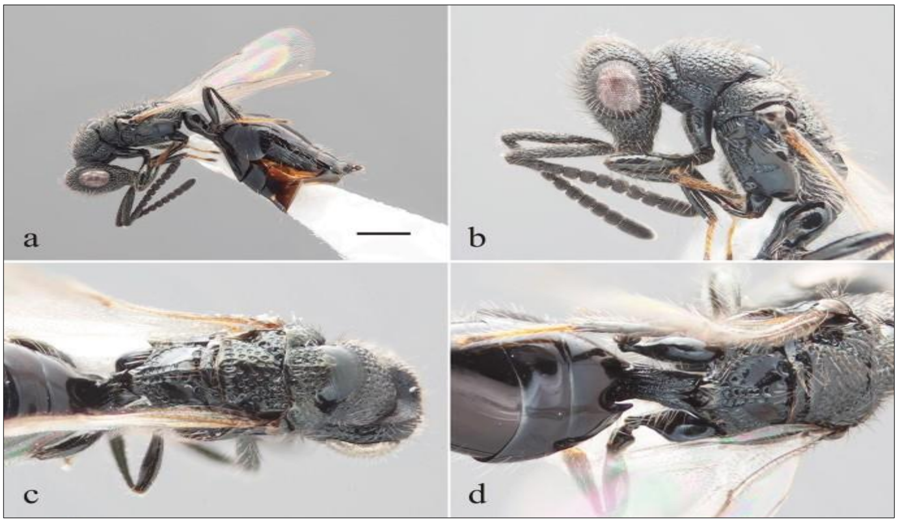


Figure 14 Four species of *Spalangia* Latreille (Hymenoptera: Pteromalidae), *Spalangia cameroni* Perkins, 1910 *Spalangia endius* Walker, 1889, *Spalangia nigroaenea* Curtis, 1839, and *Spalangia nigra* Latrielle, 1830, were collected from dairy farms located in Fukuoka, Japan; (Source: https://link.springer.com/article/10.1007/s13355-019-00656-8)

Regarding the preference of parasitoids for their hosts, it was found that *P. vindemmiae* was found parasitizing pupae of *Ravinia belforti*, Prado and Fonseca, 1932 (Diptera: Sarcophagidae), *S. cameroni* found in pupae of *Brontaea debilis* (Williston, 1896), *B. quadristigma* and *Musca domestica* L. 1758 (Diptera: Muscidae), *S. drosophilae* on *Archisepsis scabra* Loew, 1861 and *Palaeosepsis* spp. (Diptera: Sepsidae), *S. endius* in *B. quadristigma* and *Palaeosepsis* sp. pupae, *S. nigra* in

Cyrtoneurina pararescita Couri, 1995 (Diptera: Muscidae) and *R. belforti* and *S. nigroaenea* pupae in *B. debilis* pupae *B. quadristigma* and *C. pararescita* (l2= 66.71; GL: 30; P<0.05) [23].

3.4 Study 4

The aim of this study was to verify the *Spalangia* species associated with dipterans pupae buffalo feces collected in the municipality of Itumbiara, GO.

Five *Spalangia* species were collected from 2627 Diptera pupae, of which 68 pupae were parasitized by 68 parasitoids, in the period from May to December 2003. 14 specimens of *Spalangia cameroni* Perkins, 1910, 36 specimens of *Spalangia drosophilae* Ashmead, 1885, 04 specimens of *Spalangia endius* Walker, 1889*s* (Walker), 01 specimen of *Spalangia nigra* Latrielle, 1830) and 13 specimens of *Spalangia nigroaenea* Curtis, 1839 [24].

The total number of parasitism observed was 2.59% (68/2627). The prevalences of parasitism of *S. cameroni, S. drosophilae, S. endius, S. nigra and S nigroaenea* were 0.53%, 1.37%, 0.15%, 0.04 and 0.49%, respectively (Figure 15) [24].

Figure 15 *Spalangia* attacking Diptera pupae; (Source: https://bugsforbugs.com.au/product/fly-parasites/)

Spalangia drosophilae was the most collected species with 52.9% and it was also the species that presented the highest prevalence of parasitism with 1.37%. *Spalangia nigroaenea* was the second most collected species with 19.1% and showed a higher prevalence of parasitism in *Cyrtoneurina pararescita* Couri 1995 (Diptera: Muscidae) pupae with 5.26%. Regarding the preference of parasitoids for their hosts it was verified that *S. cameroni* presented preference for *Brontaea debilis* (Williston*,* 1896) (Diptera: Muscidae) and *Palaeosepsis* sp. (Diptera: Sepsidae); *S. nigroaenae* also showed preference for *D. debilis; S. drosophilae, S. endius* and *S. nigroaenea* showed preference for *Sarcophagula occidua* (Fabricius, 1794) (Diptera: Sarcophagidae) and *S. nigra* and *S. nigroaenea* by *C. pararescita* (X2 = 2420.5; P<0.005; GL:16) [24].

3.5 Study 5

The *Pteromalus albipennis* Walker, 1835, species group currently comprises 29 Palaearctic parasitoid wasp species associated with tephritid fly larvae developing in flower heads of Asteraceae (Figures 16, 17, 18, 19 and 20) [25].

Figure 16 *Pteromalus albipennis* Walker, 1835 species group and other species of the genus (Hymenoptera: Chalcidoidea: Pteromalidae); (Source: https://bdj.pensoft.net/article/27722/element/5/3770226/)

Since the reconstructions of ancestral states bear some uncertainty, contMap also provides probability values for the character states at internal nodes.

We collected on average 455,860 raw reads per species, 426,936 of which were retained after quality trimming. Assembly of the reads resulted in 411–4,520 contigs per species with contig lengths between 200 and 9,427 bp. The average assembly size was 909,241 bp. The assemblies contained between 123 and 126 target genes (mean: 125.2; 99.3% of the target genes) [25].

Figure 17 *Pteromalus albipennis* Walker, 1835 *Pteromalus* is a genus of wasps parasitising a wide variety of insect hosts, including some commercially significant Lepidoptera pests (such as on cabbage whites). Characters (from Bouček 1988): Antenna inserted near to center of face, with two anelli and six funicular segments; lower face with radiating striation; clypeus not large, poorly delimited; collar with distinct transverse carina or rectangular edge; prepectus small, horizontally shorter than tegula; scutellum mainly bare; propodeum mostly without strong plicae, propodeal apex broad, adpetiolar margin low; (Source: http://taxondiversity.fieldofscience.com/2013/09/pteromalus.html)

The species group is taxonomically challenging because their putative species are morphologically extremely like each other, except for some ovipositor length differences. The length of the ovipositor dictates the accessibility of host larvae to the female parasitoid and therefore largely determines the host range of a species. Taxonomic ambiguities and the scarce knowledge about the biology of the analyzed species highlight the difficulties of studying parasitoid wasps, even in the Western Palearctic, and despite the application of integrative taxonomic approaches (that is, the use of hundreds of genes for taxonomy) [25].

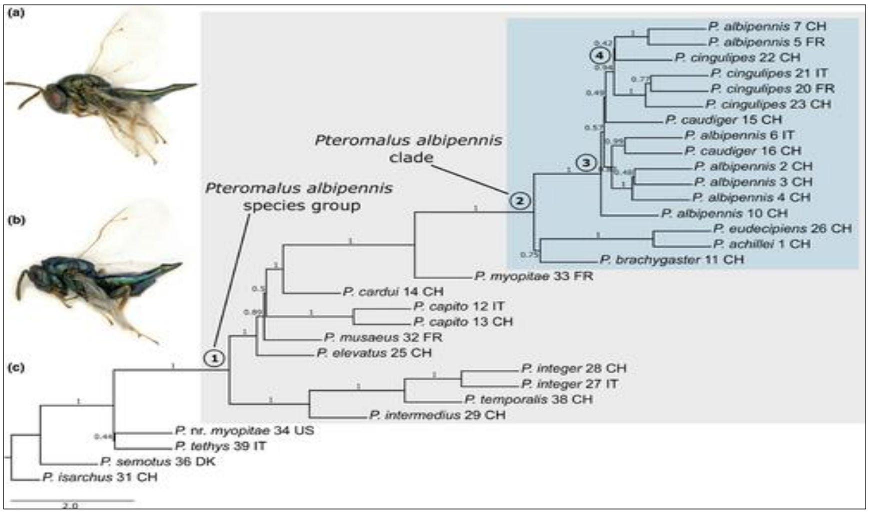


Figure 18 (a) Habitus of female *Pteromalus temporalis* (Graham, 1969) in lateral view; (b) Habitus of female *Pteromalus albipennis* Walker, 1835 in lateral view; (c) *Multispecies coalescent* (MSC) tree inferred with ASTRAL, with all weakly supported nodes (<10% bootstrap support) collapsed in the underlying gene trees. Branch support values are labeled above each branch. Branch lengths are given in coalescent units; (Source: http://taxondiversity.fieldofscience.com/2013/09/pteromalus.html)

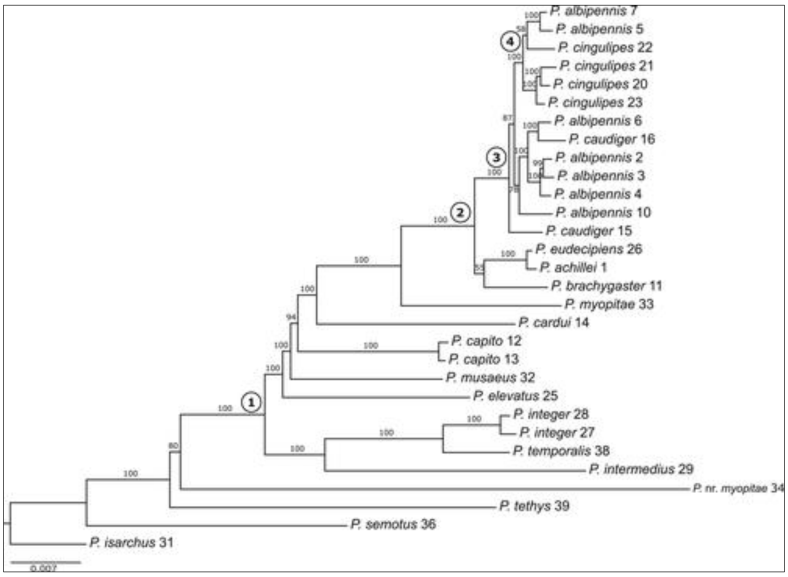


Figure 19 Tree inferred from analyzing the concatenated supermatrix under the Maximum likelihood criterion (ML), with bootstrap support values. Nodes with circles are referred to in the text; (Source: http://taxondiversity.fieldofscience.com/2013/09/pteromalus.html)

In all inferred trees, *Pteromalus elevatus* Walker 1834, *Pteromalus museus* (Walker, 1834), *Pteromalus capito* Baur, 2018., *Pteromalus cardui* (Erdos, 1953), and *Pteromalus myopitae* (Graham, 1969) are placed as five separate lineages after the Split of the *Pteromalus intermedius* Förster, 1841*, Pteromalus integer* Walker, 1872, *Pteromalus temporalis* (Graham, 1969) clade. All trees furthermore display a well-supported *Pteromalus albipennis* Walker, 1835. clade All species included here (i.e., *P. albipennis*, *Pteromalus achillei* Janzon, 1984, *Pteromalus eudecipiens* Ozdikmen, 2011, *Pteromalus brachygaster* (Graham, 1969), *Pteromalus caudiger* Graham, 1969, and *Pteromalus cingulipes* Walker, 1835 are morphologically very similar to each other. *Pteromalus achillei* Janzon, 1984, *Pteromalus brachygaster* (Graham, 1969)., and *Pteromalus eudecipiens* Özdikmen, 2011 form a moderately well-supported clade, which is sister to the well-supported clade comprising the remaining samples within the *P. albipennis* clade. Within this clade of *P. albipennis*, *P. caudiger*, and *P. cingulipes*, most internal branches are conspicuously short and only some subclades are well supported [25].

In addition, the topologies of the different trees are not fully congruent within this clade. However, in none of the trees are *P. caudiger*, *P. cingulipes* or *P. albipennis* found to be monophyletic. *Pteromalus caudiger* appears to be polyphyletic, while the *P. cingulipes* samples cluster with strong support with two samples of *P. albipennis*, rendering both species paraphyletic [25].

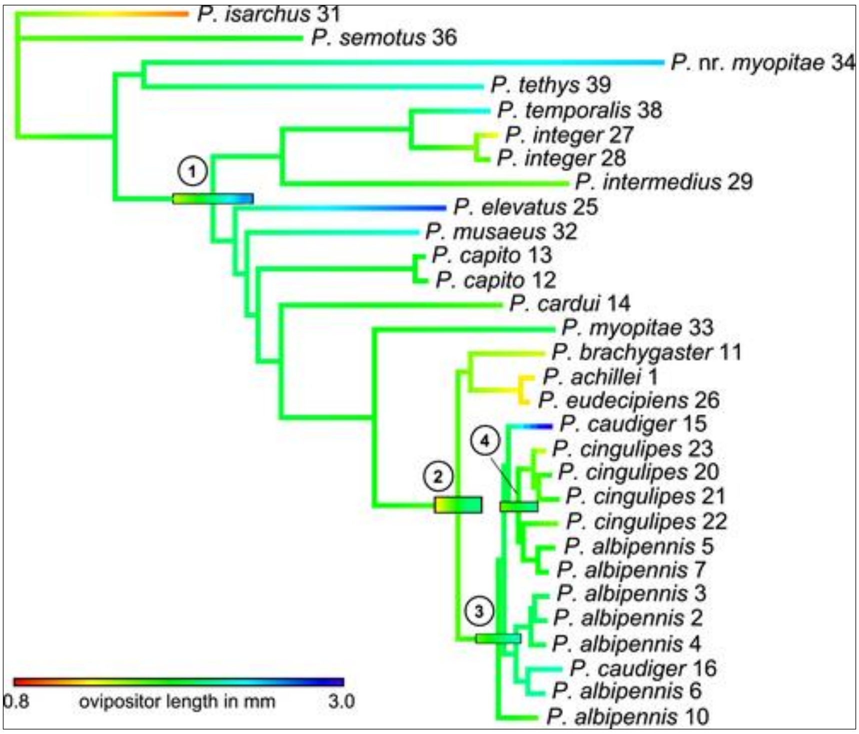


Figure 20 Gaster/ovipositor length variation. The colors illustrate the observed and the reconstructed ancestral values for the absolute gaster length (a proxy for ovipositor length); boxes at selected nodes indicate probabilities for inferred ancestral states; (Source: http://taxondiversity.fieldofscience.com/2013/09/pteromalus.html)

While there are certain clades that share a common ovipositor length (e.g., *P. achillei*, *P. brachygaster*, and *P. eudecipiens*, which share a short ovipositor), there is no obvious evolutionary tendency across the phylogenetic tree, that is, there are no major transition from a longer to a shorter ovipositor or vice versa. Despite considerable uncertainty in the ancestral state reconstructions, it can be inferred that the most recent common ancestor of the *P. albipennis* species group possessed a comparatively long ovipositor, while it was of medium length in the most recent common ancestor of the *P. albipennis* clade [25].

4 Conclusion

Pteromalidae have solitary and gregarious species, living outside (ectoparasitoids) or inside their prey (endoparasitoids), koinobionts and idiobionts, primary parasitoids and hyperparasitoids and even predators that kill and consume the prey immediately; they also include genera of fig wasps. Due to their parasitoid nature, wasps in this family are often used as biological control agents for destructive pests such as serpentine mines and monarch butterfly.

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