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Studies on the families Drynidae, Heloridae and Ismaridae (Insecta: Hymenoptera)

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Abstract

Most Dryinidae act as cenobiont ectoparasitoids of Cicadellidae, Delphacidae, Flatidae and Membracidae (Hemiptera). Females of Dryinidae feed on nectar and other sugary solutions and, with the exception of Aphelopinae, they also have a predatory habit and feed on fluids and tissues of their hosts. Only *Crovettia* Olmi (Aphelopinae) act as polyembryonic endoparasitoids that attack Membracidae nymphs. The Heloridae Family Individuals of this family are solitary, endoparasitoids of Chrysopidae (Neuroptera) larvae, and use the cocoon created by the host to complete their cycle. The Family Ismaridae are primary parasitoids of cicadas (Hemiptera: Cicadellidae). Species of *Ismarus* act as hyperparasitoids or secondary parasitoids of larvae of Dryinidae (Hymenoptera). This paper aims to seek knowledge about the Drynidae, Heloridae and Ismaridae families. The methodological basis of the present work consists of bibliographical research of scientific articles published in national and international academic scientific journals classified by the Coordination for the Improvement of Higher Education Personnel (CAPES). The search criterion for articles was to prioritize articles that dealt with the topic. Document analysis was used as a data collection method to gather information in theoretical books, theses banks, university dissertations, scientific journals, documents and digital platforms of the University of São Paulo (http://www.usp.br/), Latin American and Caribbean Literature in Health Sciences (http://www.bireme.br/), Scielo (http://www.scielo.org) and University of Brasilia (http://www.bce.unb.br/sistemas/pesq_bibliografica.php).

Keywords: Parasitoid primary; Parasitoid Secondary; Cicadellidae; Chrysopidae

1 Introduction

There are approximately 14. 800 Hymenoptera species in Australia and it is estimated that 4.000 of these are ant species. The name Hymenoptera means 'membrane wings'. This order is large and diverse and includes groups of insects, which may appear to be unrelated due to their differing appearances [1,2]. However, all hymenopterans share the following characteristics:

The forewings are larger than the hind wings and are held together by small hooks (see below). Females usually have a hardened ovipositor, which may be modified for sawing, piercing, or stinging. Most hymenopterans have a constriction between the first 2 segments of the abdomen, which is known as a 'wasp waist. Chewing (mandibulate) mouthparts, although in some species such as bees the lower lip is modified to form a tongue [1,2].

The larvae of hymenopterans lack many of the above external features. They vary in body shape and size depending on the species. Some display a distinct head thorax with 3 pairs of legs and an abdomen, although most are grub-like with no legs [1,2].

The Hymenoptera is divided into 2 suborders. The Symphyta (sawflies) who have no discernible waist and Apocrita (ants, bees and wasps) have a distinct waist. The Hymenoptera are quite a distinctive order and members are unlikely to be confused with other insects. Some smaller-winged species may appear to only have 1 pair of wings and may be

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mistaken for flies (Diptera). Sawfly larvae are very caterpillar-like in appearance and may be mistaken for caterpillars (Lepidoptera) [1,2].

Hymenopterans have a complete life cycle, which varies slightly depending on the species. Some females can produce young without mating, while others can store sperm and spread out their egg-laying to coincide with available food. Most species will lay their eggs on the appropriate host plant or on paralyzed food sources they have gathered into specially constructed nests [1,2].

Objective

This paper aims to seek knowledge about the Drynidae, Heloridae and Ismaridae families

2 Material and methods

The methodological basis of the present work consists of bibliographical research of scientific articles published in national and international academic scientific journals classified by the Coordination for the Improvement of Higher Education Personnel (CAPES). The search criterion for articles was to prioritize articles that dealt with the topic. Document analysis was used as a data collection method to gather information in theoretical books, theses banks, university dissertations, scientific journals, documents and digital platforms of the University of São Paulo (http://www.usp.br/), Latin American and Caribbean Literature in Health Sciences (http://www.bireme.br/), Scielo (http://www.scielo.org) and University of Brasilia (http://www.bce.unb .br/sistemas/pesq_bibliografica.php)

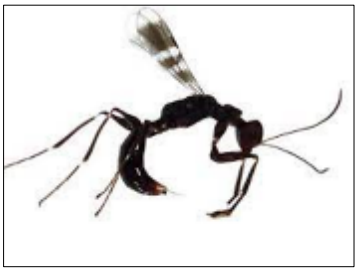
3 Family Drynidae

3.1 Introduction

The Chrysidoidea act as parasitoids of Phasmatoidea eggs, as ectoparasitoids of Cicadellidae, nymphs of Embioptera or larvae of Lepidoptera Coleoptera; some are kleptoparasitoids in nests of kleptoparasites. Dryinidae is cosmopolitan and its species can be found in almost all terrestrial environments, from sea level to altitudes above three thousand meters (Figures 1-3) [3,4].

Source: https://species.wikimedia.org/wiki/Gonatopus_alpinus

Figure 1 *Gonatopus alpinus* Gourlay, 1954 female: *Gonatopus* is a genus of flowering plants in the Araceae family, comprising 5 validly described species. The genus is native to eastern and southern Africa and is closely related to the genus *Zamioculcas*



Source: Photo 1209742, (c) Stephen Thorpe, all rights reserved, uploaded by Stephen Thorpe and Source: https://en.wikipedia.org/wiki/Dryinidae

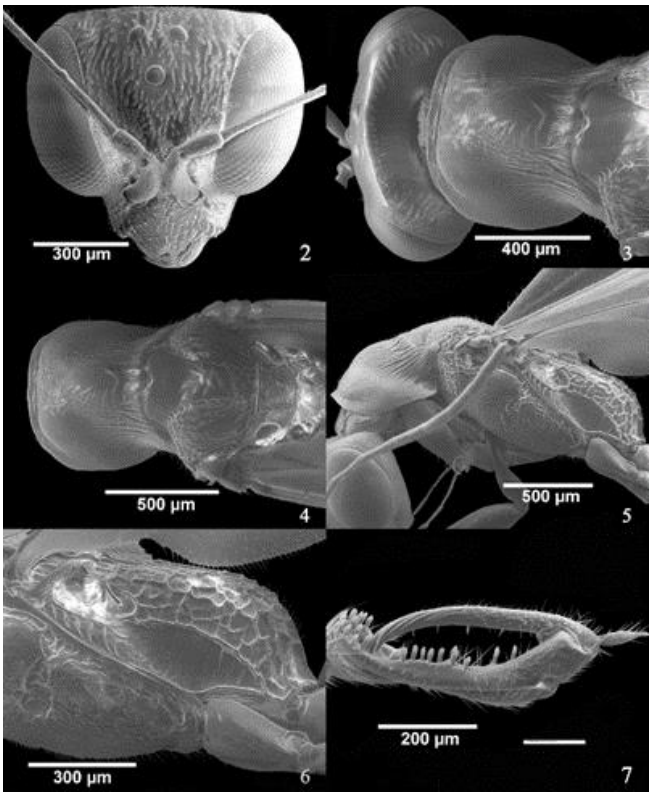
Figure 2 *Dryinus koebelei* (Perkins, 1905). Specimen of Drynidae Family

Source: https://www.mapress.com/zt/article/view/zootaxa.4630.1.1/0

Figure 3 Dryinidae of the Afrotropical region (Hymenoptera, Chrysidoidea)

3.2 Description

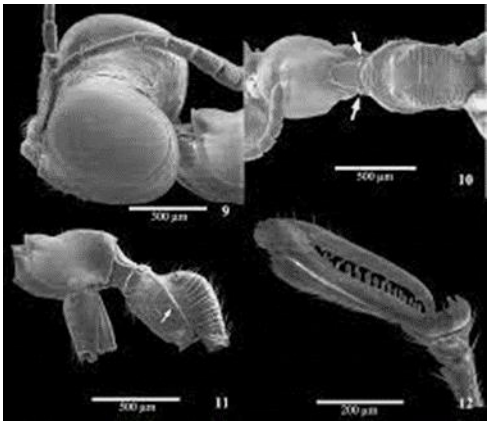
Mesosoma with well-developed pronotum anteriorly, with posterolateral tubercles that touch or not the tegules; wings forewings with one to three (occasionally four) cells closed by pigmented veins and hindwings without closed cells and jugal lobe; formula of tibial spurs in males is 1-1-2 and variable in females (Figure 4) [3,4,5].



Source: https://www.scielo.br/j/bjb/a/4kNWW7V8KJqc633ZJKdkkdv/?lang=en#ModalFigf27

Figure 4 fig. 2-7 *Dryinus auratus* sp. nov. Female. 2. Head, frontal view. 3. Head, dorsal-posterior view. 4. Mesosome, dorsal view. 5. Mesosome, lateral view. 6. Propodeum, side view. 7. Claw

Sexual dimorphism ranges from mild to very marked, making it difficult to associate females with their respective males - this explains that the taxonomy of Dryinidae is based mainly on females. The Dryinidae have an ovipositor capable of laying eggs in different regions of the body of their hosts, unlike most of the Aculeata (Figure 5) [5,6,7].



Source: https://www.scielo.br/j/bjb/a/4kNWW7V8KJqc633ZJKdkkdv/?lang=en#ModalFigf912

Figure 5 fig. 9-12 *Gonatopus mariae* sp. nov (Paratype). Female. 9. Head, dorsolateral view. 10. Dorsal mesosoma view. 11. Mesosoma and propedum, lateral view. 12. Claw

3.3 Biology

Most Dryinidae act as cenobiont ectoparasitoids of Cicadellidae (Cicadelloidea), Delphacidae, Flatidae and Membracidae (Hemiptera). Females of Dryinidae feed on nectar and other sugary solutions and, with the exception of Aphelopinae, they also have a predatory habit and feed on fluids and tissues of their hosts. Only *Crovettia* Olmi (Aphelopinae) act as polyembryonic endoparasitoids that attack Membracidae nymphs (Figure 6) [8,9,10].

Source: https://brill.com/view/journals/ise/52/2/article-p167_167.xml

Figure 6 Interactions between dryinids and their hosts are poorly known in the Neotropical region, especially for the Brazilian fauna. This study aims to expand this incipient knowledge by describing a new species of Anteon Jurine and four new species of *Gonatopus* Ljungh reared from parasitized leafhoppers (Cicadellidae) collected in the state of Paraná, Southern Brazil. The new species, *Gypona elianeae* sp. nov., *Gypona josei* sp. nov., *Gypona meloi* sp. nov., *Gypona pinhalensis* sp. nov. and *Gypona taquarensis* sp. nov., are associated with leafhopper. Species of Dryinidae parasitizing the leafhoppers species: *Curtara (Curtara) concava* (DeLong & Freytag, 1976)., *Gypona lita* and *Reticana lineatta* (Gyponini), *Graminella striatella* (Deltocephalini) and *Copidinomus vittulatus* (Pendarini)

Superparasitism is reported for some female Gonatopodinae. Drynidae have biparental reproduction or parthenogenetic thelytok or arrhenotoky. Dryinidae species can be bi or multivoltine, according to the region where they live; as they are not good fliers, their ability to disperse depends more on their hosts than on themselves. Many females of Gonatopodinae associated with leafhoppers are wingless and resemble ants; they take advantage of this similarity to capture their prey and perform parasitism (Figures 7-8) [11,12,13].

Source: https://www.fredmiranda.com/forum/topic/788852

Figure 7 *Issus coleoptratus* (Fabricius, 1781) (Hymenoptera: Drynidae) nymph with dryinid larva under the right wing. Found a plant hopper nymph with a parasitic larva lodged under a winglet. Looks rather similar to the wasp larvae you sometimes get on *Araniella* spiders possibly ID as Dryinid (primitive aculeate wasps) from the WAB website

Source: https://bugguide.net/node/view/979835

Figure 8 Drynidae larva ectoparasitoids parasitizing cicada ectoparasitoid Cicadellidae

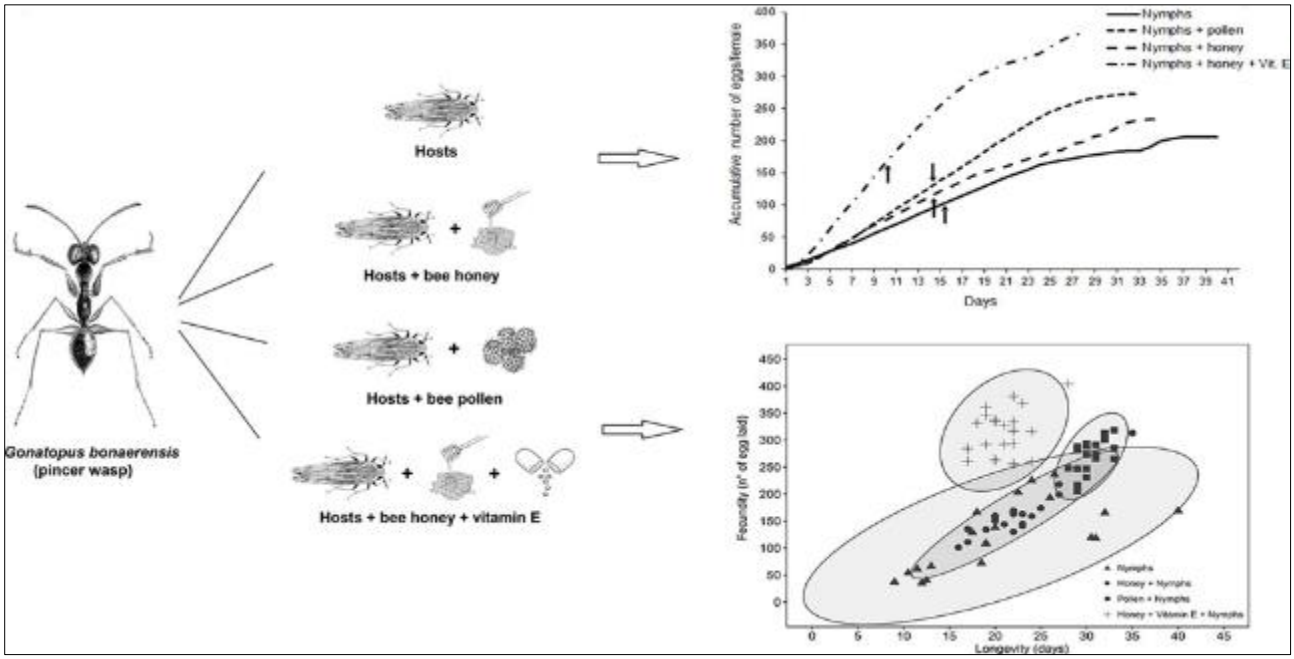
Dryinidae locates their hosts; there is a chance that localization occurs through the perception of substances excreted by the hosts. Some species of Drynidae have been used in biological control programs: *Gonatopus nigricans* (Perkins, 1905) and *Haplogonatopus vitiensis* (Perkins, 1905) were introduced in Hawaii in the second half of the 1990s to control *Perkinsiella saccharicida* Kirkaldy, 1905 (Hemiptera, Delphacidae) which causes damage to sugarcane crops (Figure 9) [14,15,16].

Source: https://nathistoc.bio.uci.edu/hymenopt/Dryinidae%20larvae.htm, Photo 32144560, Stephen Thorpe, some rights reserved, uploaded by Stephen Thorpe and https://www.biodiversity4all.org/photos/32144560

Figure 9 Dryinid Wasp larvae, a parasite on planthopper's and *Dryinus koebelei* (Perkins, 1905)

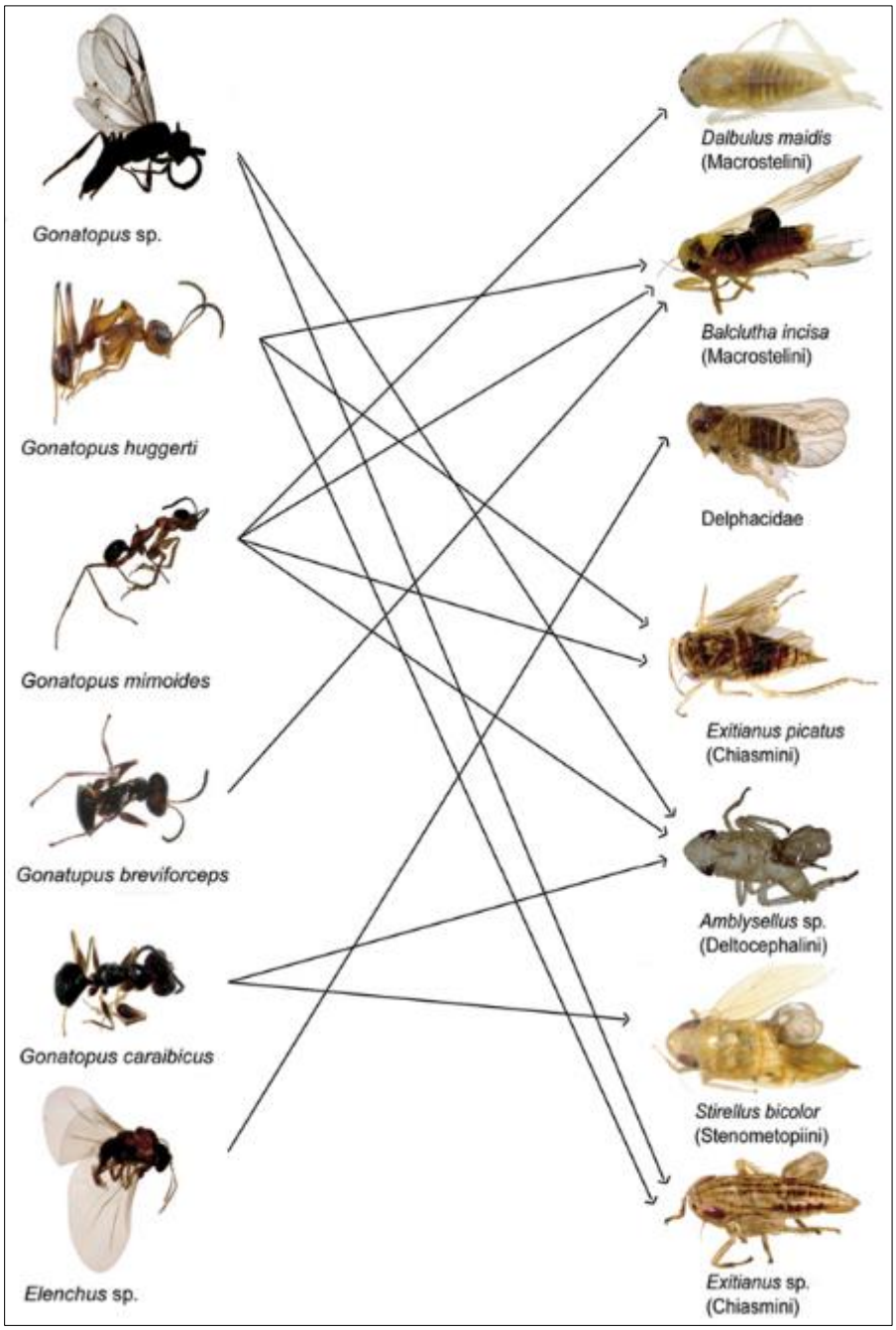
3.4 Biocontrol

Aphelopus albopictus Ashmead, 1893 was introduced in 1935 in New Zealand for the control of *Edwarsiana crateagi* (Douglas, 1873) (Cicadellidae: Typhlocybinae) in apple cultivation and *Neodryinus typhlocybae* (Ashmead, 1893) was introduced in Italy, France, Slovenia and Switzerland for the control of *Metcalfa pruinosa* (Say, 1830) (Flatidae) in ornamental plants. Almost nothing is known about the biology and relationships of the Drynidae with their hosts, which makes their use in biological control programs difficult (Figures 10-11) [17,18,19].



Source: https://en.x-mol.com/paper/article/1391827567197704192

Figure 10 Marked differences were verified in longevity, fecundity, host-feeding and parasitism levels when the diet of females was supplemented with pollen, bee honey, or with honey + vitamin E. The addition of pollen to the diet significantly increased the longevity of females. In concordance with the record of a greater number of eggs laid throughout their lives, pincer wasp females provided with nymphs + honey + vitamin E parasitized significantly more host nymphs and carried out fewer host-feeding activities than those maintained under other diets. When females had access to supplementary food sources, the concurrent host-feeding decreased, increasing the effectiveness of this pincer wasp. Even though a good number of hosts were healthy after the exposure period, greater phenomena of self-superparasitism were recorded in females that received alternative food sources

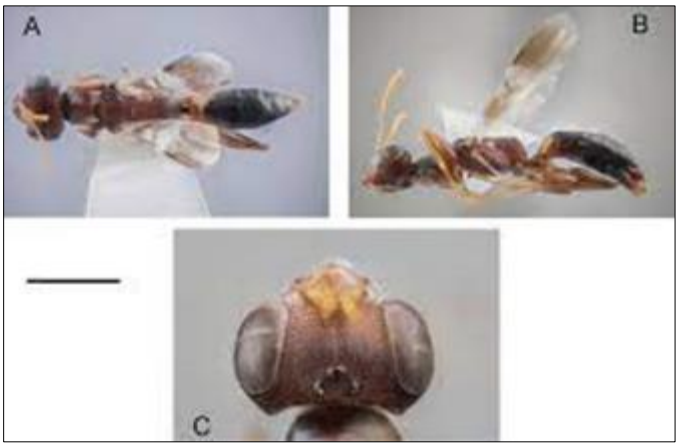


Source: https://jhr.pensoft.net/article/12990/

Figure 11 Total of parasitoid-host interactions found on the edges of maize agroecosystem in the winter seasons of 2014 and 2015. The name in parenthesis shows the name of the host tribe

3.5 Taxonomy

Dryinidae is home to approximately 270 species of which 110 are reported for the Neotropics and of these, about 40 have occurrence records for Brazil. Dryininae is home to about 340 species grouped into nine genera, of which three are fossils. Among the Dryininae *Dryinus* Latreille is the only genus present in all zoogeographic regions (Figure 12). [20,21,22,23].



Source: https://zookeys.pensoft.net/article/35974/zoom/fig/11/

Figure 12 *Dryinus* female holotype: habitus in dorsal (A) and lateral (B) view; head in dorsal view (C). Scale bars: 1.28 mm (A, B); 0.46 mm (C)

Dryinidae is cosmopolitan, with about 1700 described species grouped into 48 genera and 14 subfamilies; for the Neotropics Aphelopinae, Anteoninae, Bocchinae, Gonatopodinae, Apodryininae and Dryininae are reported, which include 22 genera and about 470 species. Chrysidoidea, one of the 21 hymenopteran superfamilies, is monophyletic and comprises seven families, including Dryinidae, all present in the Neotropics (Figure 13) [24,25,26,27].

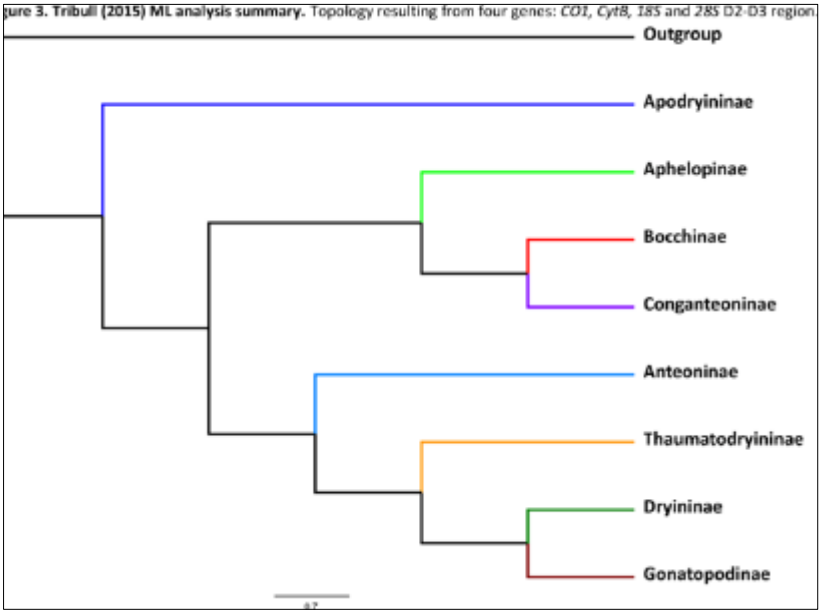


Figure 13 Tribull (2015) ML analysis summary. Topology resulting from four genes: CO1, CytB, 18S and 28S D2-D3 region

4 Studies selected and carried out

4.1 Study 1

4.1.1 Dryinidae (Hymenoptera: Chrysidoidea) of Paraguay new reports

A- Subfamily Aphelopinae [28,29].

Aphelopus jamaicanus Olmi, 1984

Distribution: Mexico; Cuba; Jamaica; Netherlands Antilles; Hondura; Costa Rica; Panama; Colombia; Venezuela; Puerto Rico; Cuba; Argentina; Uruguay; Paraguay.

Aphelopus ocellaris Olmi, 1989

Distribution: Brazil; Paraguay.

B-Subfamily Anteoninae

Panamanian anteon Olmi, 1989

Distribution: Mexico; Belice; Honduras; Nicaragua; Costa Rica; Panama; Venezuela; Ecuador; Peru; Brazil; Argentina; Paraguay [28,29].

Deinodryinus atlanticus Olmi, 1984

Distribution: Mexico; Nicaragua; Costa Rica; Panama; Ecuador; Brazil; Argentina; Paraguay [28,29].

Deinodryinus incaicus Olmi, 1989

Distribution: Dominica; Costa Rica; Panama; Venezuela; Colombia; Ecuador; Brazil; Bolivia; Argentina; Paraguay [28,29].

Deinodryinus noyesi Olmi, 1984

Distribution: Mexico; Guatemala; Hondura; Costa Rica; Trinidad And Tobago; Colombia; Venezuela;

Southern; Ecuador; Peru; Brazil; Bolivia; Argentina; Paraguay [28,29].

Deinodryinus peruvianus Olmi, 1984

Distribution: Costa Rica; Trinidad And Tobago; Colombia; Venezuela; Ecuador; Peru; Bolivia;

Brazil; Argentina; Paraguay [28,29].

Deinodryinus trinity Olmi, 1984

Distribution: Mexico; Hondura; Costa Rica; Trinidad And Tobago; Venezuela; Colombia; Brazil; Argentina; Paraguay [28,29].

C- Subfamily Dryininae

Dryinus atrox Olmi, 1989

Distribution: Costa Rica; Panama; Paraguay [28,29].

Dryinus febrigi Olmi, 1984

Distribution: Paraguay [28,29].

Dryinus pegnai Olmi sp. nov.

Distribution: Panama; Ecuador; Peru; Paraguay [28,29].

Dryinus surinamensis Olmi, 1984

Distribution: Mexico; Hondura; Costa Rica; Panama; Colombia; Southern; Ecuador; Peru; Brazil;

Paraguay [28,29].

D-Subfamily Gonatopodinae

Gonatopus contortus Olmi, 1984

Distribution: Argentina; Bolivia Paraguay [28,29].

Gonatopus huggerti Olmi,1992

Distribution: Peru; Paraguay [28,29].

Neodryinus forest Olmi sp. nov.

Distribution: Paraguay [28,29]. *Trichogonatopus albomarginatus* (Cameroon, 1485)

Distribution: Costa Rica; Panama; Colombia; Venezuela; Brazil; Argentina; Paraguay [28,29].

4.2 Study 2

4.2.1 Corn Spittlebug: See how to identify it, what are its damages corn, its relationship with stunting disease and the best handling.

Among the diversity of insects that cause damage to agriculture, the corn leafhopper *Dalbulus maidis* Delong & Wolcott, 1923) (Homoptera: Pentatomidae) is currently considered one of the most severe pests in Latin America. This leafhopper specializes in maize plants and the problem occurs because it sucks the sap of the plants and transmits viruses and mollicutes from corn stunting [30].

Infestation by *D. maidis* has increased in several regions of Brazil, causing the disease it transmits (sickness) to also gain more and more importance. Production losses of 70% or more are observed in corn fields in the South, Goiás, Triângulo Mineiro, northwest Minas Gerais and other regions of the country. Faced with this problem, it is necessary to understand more about the bioecology, vector behavior and its interaction with the maize stunting complex in order to improve its management [30].

The corn leafhopper *D. albulus* maidis belongs to the order Hemiptera and the family Cicadellidae. They are small-sized insects, measuring 0.4 cm, with a white to straw color and two black spots on the dorsal part of the head. Individuals have an embryonic period of 5 to 10 days, a nymph stage of 14 to 16 days, taking an average of 24 days to reach the adult stage. This phase has an average longevity of 45 days, which varies within the same population and with the ambient temperature [30].

4.2.2 What does the sharpshooter do with the corn?

These insects cause injuries to maize plants by sucking sap, injecting toxins and transmitting phytopathogens, especially those related to stunting. The leafhopper becomes a transmitter of these phytopathogens after feeding on an infected plant. For this, the insect needs a few seconds or hours of suction to acquire and later transmit phytopathogens to other maize plants.

Leafhopper adults can feed on other plants in the corn family, but they only reproduce in corn plant pods. In the off-season, leafhoppers survive and multiply in corn stalks or other corn crops to which the adults disperse by flight [30].

4.2.3 Biological control

For the biological control of corn leafhoppers, the entomopathogenic fungus *Beauveria bassiana* (Balsamo) Vuillemin, 1912 (Moniliaceae) is usually used. In countries like Argentina and Mexico, parasitoids of *D. maidis* are studied, which can be divided into two categories: those that parasitize eggs and those that parasitize nymphs and adults.

Egg parasitoids belong to the family Mymaridae and Trichogrammatidae (Hymenoptera: Chalcidoidea), while those of nymphs and adults are species of Dryinidae (Hymenoptera) [30].

4.3 Study 3

Dryinidae (Hymenoptera, Chrysidoidea) has a cosmopolitan distribution and acts as ecto and endoparasitoids of nymphs and leafhopper adults (Hemiptera, Auchenorryncha). In Brazil, 5 subfamilies, 15 genera, and approximately 150. This study aimed to identify the species of Dryinidae collected with a Moericke trap in a forest [31].

Of a gallery in the Municipality of Pratápolis. The collections were carried out using a Moericke trap. A total of 11 specimens of Dryinidae belonging to 3 subfamilies were obtained: Aphelopine, Anteoninae and Gonatopodinae. Of Aphelopinae, it was recognized only one species *Aphelopus difusus* Olmi, 1984; of Anteoninae, four species were recognized: *Deinodryinus costaricanus* Olmi, 1987, *Deinodryinus elegans* Olmi,1984 and *Deinodryinus speciosus* Olmi, 1984 [31].

4.4 Study 4

Dryinidae (Hymenoptera, Chrysidoidea) has a cosmopolitan distribution and, in the Neotropics, are recognized approximately 500 species contained in 22 genera and 6 subfamilies: Anteoninae, Aphelopinae, Apodryininae, Bocchinae, Dryininae and Gonatopodinae. For Brazil, 15 genera and approximately 150 species and 5 subfamilies are registered [32],

The Dryinidae act as ecto and endoparasitoids of leafhopper nymphs and adults (Hemiptera, Auchenorryncha). This study aimed to identify the genera of Dryinidae collected in the Serra da Canastra National Park (PNSC), a municipality from São Roque de Minas, in Minas Gerais. The material studied comes from the INCT Project – HYMPAR/Southeast, collected using a Malaise trap and sweep net [32].

A total of 84 specimens of Dryinidae were obtained, belonging to 5 subfamilies: Aphelopinae, Anteoninae, Bocchinae, Dryininae and Gonatopodinae. From Aphelopinae, the 2 genera recognized in the subfamily, *Aphelopus* Dalman, were collected, with a total of 44 specimens (representing 52.38% of the total collected), and *Crovettia* Olmi, all males; of Gonatopodinae, was recognized only *Gonatopus* Ljungh, with a total of 10 specimens (representing 11.90% of the total collected), of which 8 are females and 2 males; of Bocchinae only *Bocchus* Ashmead was recognized (6 specimens/7.14%), all males; of Anteoninae, two genera were recognized, *Anteon* Jurine (4 specimens/4.74%), all females, and *Deinodryinus* Perkins (6/7.14%), all mal, and of Dryininae, only *Dryinus* Latreille (3/3.57%) was recognized, of which 2 females and 1 male (Figures 14-15) [32].

Source: https://nl.wikipedia.org/wiki/Aphelopus

Figure 14 Genus *Aphelopus* (Drynidae)

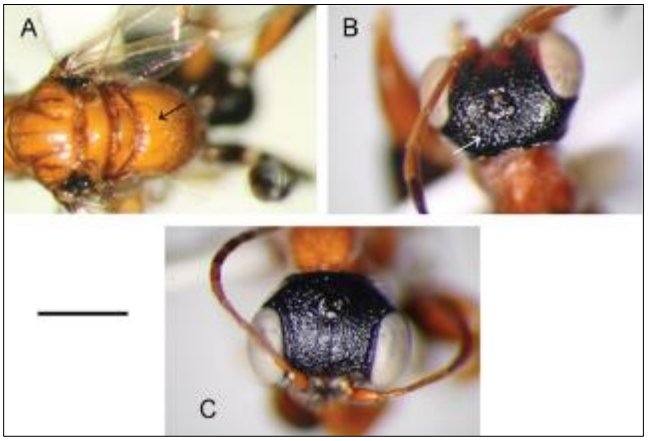
Source: http://www.waspweb.org/Chrysidoidea/Dryinidae/Gonatopodinae/Gonatopus/index.htm

Figure 15 Genus *Gonatopus* (Drynidae)

The Dryinidae are a group of parasitoid wasps poorly sampled in the vast majority of existing surveys, a pattern also observed in this study, considering the data collection period (approximately 15 months). Comparing the ratio of males and females, males represented more than 80% of the total specimens collected. All Dryinidae subfamilies and about 50% of the genera that occur in Brazil are represented in the PNSC (Figures 16-19) [32].

Source: http://www.waspweb.org/Chrysidoidea/Dryinidae/Anteoninae/Anteon/Anteon_blacki.htm

Figure 16 Genus *Anteon (*Drynidae**)**



Source: https://zookeys.pensoft.net/article/30647/

Figure 17 *Deinodryinus*: female from Arizona, Madera Canyon: A mesosoma in dorsal view C head in dorsal view. *Deinodryinus,* female from Kentucky, Herndon Farm: B head in dorsal view. Scale bars: 0.84 mm (A), 0.61 mm (B), 0.59 mm (C)

Source: https://www.scielo.br/j/bjb/a/4kNWW7V8KJqc633ZJKdkkdv/?lang=en

Figure 18 Genus *Dryinus* Drynidae

Source: http://www.waspweb.org/chrysidoidea/dryinidae/Bocchinae/Bocchus/index.htm

Figure 19 Genus *Bocchus* (Drynidae)

4.5 Study 5

In the Neotropical region, this superfamily is represented by 7 families: Bethylidae, Chrysididae, Dryinidae, Embolemidae, Sclerogibbidae, Scolebythidae and Plumariidae; which are rare. Traditionally, this superfamily is considered ectoparasitoids and its species are used in biological control: Dryinidae on leafhoppers (Insecta: Hemiptera: Cicadellidae) and Bethylidae on lepidopterans (Insecta: Lepidoptera) and Coleoptera (Insecta: Coleoptera) [33].

This study aimed to report the families of Chrysidoidea that occur in an area of Caatinga, in the Municipality of Patu, Rio Grande do Norte. Samplings were carried out with two Malaise traps [33].

The traps were installed in the native Caatinga forest, with little anthropic action, located at the foot of Serra do Lima. 732 specimens of Chrysidoidea were obtained: Bethylidae (657 specimens/89.8% of the total collected), Dryinidae (62/8.5%) and Chrysididae (13/1.8%). The most frequent months were: September for the Chrysidoidea (314) and Bethylidae (296), October for the Chrysididae (seven) and November for the Dryinidae (27) [33].

4.6 Study 6

The Dryinidae, exclusive parasitoids of Hemiptera *Auchenorrhyncha*, account for approximately 1400 species distributed on all continents, except Antarctica; their populations are affected by parasitoid hymenopterans of the families Encyrtidae, Diapriidae, Ceraphronidae, Chalcididae and Pteromalidae [34,35].

For Argentina, 122 species of Drynidae are cited of which three encrypted parasitoids are known: *Cheiloneurus cristatus* De Santis, 1957, *Cheiloneurus cupreicollis* (Ashmead): Gahan, 1914 (Hymenoptera: Encyrtidae) and *Helegonatopus pseudophanes* Perkins, 1906 (Hymenoptera: Encyrtidae) [34,35].

In Santa Maria, Catamarca, three females and two males of *Toya propinqua* (Fieber, 1866) Homoptera; - Delphacidae) were collected, four nymphs of Toya sp. and two nymphs of *Delphacodes* sp. (Hemiptera: Delphacidae) parasitized by *Gonatopus chilensis* (Olmi, 1984) (Dryinidae, Gonatopodinae) (Figure 20) [34,35].

Source: Photo 5486861, (c) Stephen Thorpe, some rights reserved (CC BY-NC), uploaded by Stephen Thorpe and https://inaturalist.ca/photos/5486861

Figure 20 Genus *Cheiloneurus* (Drynidae)

In the laboratory it was observed that two Drynidae cocoons were affected by a parasitoid whose larvae left the host in two different situations: one of them left the Drynidae larva when it was still building the cocoon, while the other emerged from a specimen. that it was in a state of prepupa; the adults of these parasitoids emerged at 25 and 27 days respectively. The specimens were identified as *Cheiloneurus cupreicollis* (Ashmead, 1894) (Hymenoptera: Encyrtidae) (Figure 21) [34,35].

Sources: Photo 109737565, (c) fotis-samaritakis, some rights reserved (CC BY-NC), uploaded by fotis-samaritakis and https://inaturalist.ca/photos/109737565

Figure 21 Genus *Cheiloneurus* (Drynidae)

Species of the genus *Cheiloneurus* Westwood, 1833 generally develop as endoparasitoids larval (primary and secondary) of microhymenoptera that affect Coccoidea, Fulgoroidea, Cicadelloidea and Lygaeidae (Hemiptera), Curculionidae and Coccinellidae (Coleoptera), as well as Syrphidae and Cecidomyidae (Diptera) [34,35].

4.7 Study 7

4.7.1 Dryinidae wasps of the Afrotropical Region

Anteoninae:

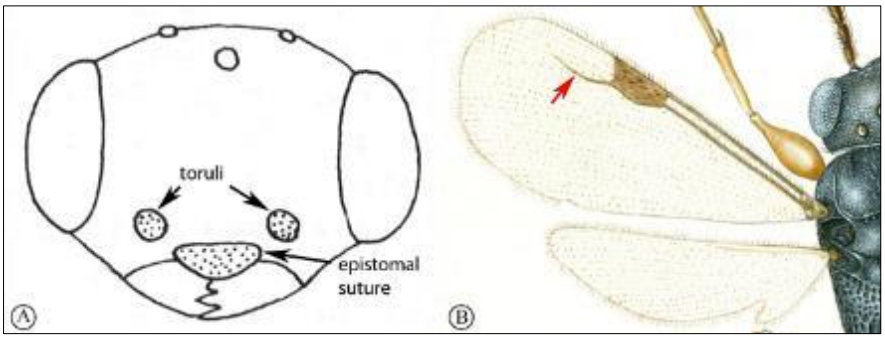
Parasitoids of Leaf hoppers: Cicadellidae (including Idiocerinae and Macropsinae) (Figures 22-28) [36,37].

Source: Photographs © Simon van Noort (Iziko Museums of South Africa).

Figure 22 Subfamily Anteoninae

Aphelopinae:

Hosts: Typhlocybinae (Cicadellidae) and Membracidae. Species of Crovettia are known for their completely diaphanous parasitism and polyembryony [36,37].



Source: http://www.waspweb.org/Chrysidoidea/Dryinidae/ and Photographs © Simon van Noort (Iziko Museums of South Africa).

Figure 23 Subfamily epistomal suture not touching antennal toruli (A); forewing with 2r-rs, Rs vein long and regularly curved (B) *Aphelopus* Dalman

Apoaphelopinae:

Host: Unknown [36,37].

Source: http://www.waspweb.org/Chrysidoidea/Dryinidae/ and Photographs © Simon van Noort (Iziko Museums of South Africa)

Figure 24 Subfamily Apoaphelopinae

Apodryininae

Host: Unknown [38].

Source: http://www.waspweb.org/Chrysidoidea/Dryinidae/ and Photographs © Simon van Noort (Iziko Museums of South Africa).

Figure 25 *Apogonatopus edaphicus* Olmi, 2007

Bocchinae

Host: Parasitoids of Issidae (Hemiptera) [39,40].

Source: http://www.waspweb.org/Chrysidoidea/Dryinidae/ and Photographs © Simon van Noort (Iziko Museums of South Africa)

Figure 26 Subfamily Bocchinae

Conganteoninae:

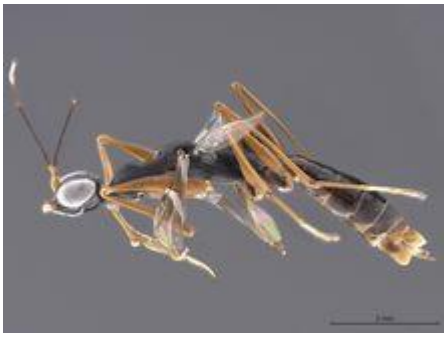
Host: unknown [39,40].

Source: http://www.waspweb.org/Chrysidoidea/Dryinidae/ and Photographs © Simon van Noort (Iziko Museums of South Africa)

Figure 27 Subfamily Conganteoninae

Dryininae

Hosts: Flatidae (Hemiptera) [39,40].



Source: http://www.waspweb.org/Chrysidoidea/Dryinidae/ and Photographs © Simon van Noort (Iziko Museums of South Africa)

Figure 28 Subfamily Dryininae

Gonatopodinae

Parasitoids of Leaf hoppers: Cicadellidae (Hemiptera) [39,40].

Hosts: Flatidae (Hemiptera) [39,40].

Source: http://www.waspweb.org/Chrysidoidea/Dryinidae/ and Photographs © Simon van Noort (Iziko Museums of South Africa)

Figure 29 Subfamily Thaumatodryininae

5 Family Heloridae

5.1 Introduction

Heloridae belonging to the superfamily Proctotrupoidea (Hymenoptera), Heloridae is a small family that contains only one genus (*Helorus*) and no more than eight described species. The family is distributed throughout the world, although its species are rarely collected (Figures 30-31) [41,42,43].

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

Figure 30 Heloridae Family

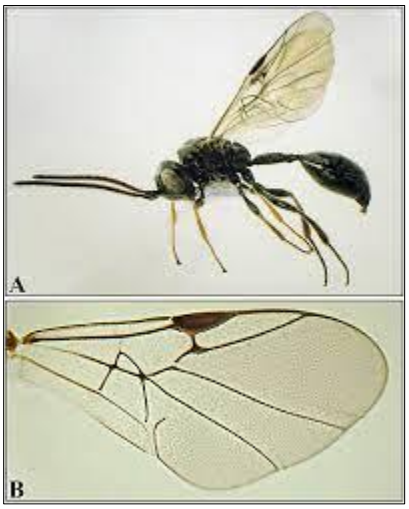
Source: https://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=173714

Figure 31 Heloridae Family

5.2 Characters

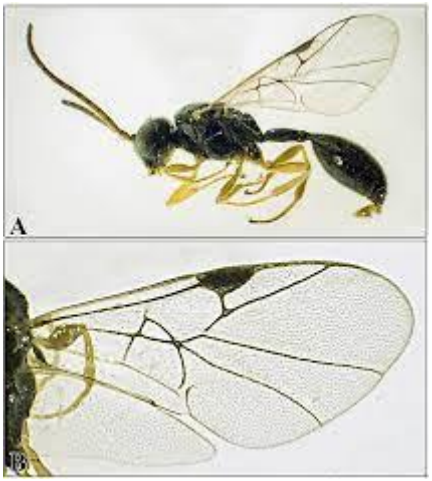
Members of this family are usually stout, metallic black, no longer than 8 mm. The antennae are filiform (15 segments) with short antennal scapes. The mesoscutum has a well-developed suture between the tegulae (transcutal suture) [44,45,46].

The veining on the wings is distinctive of the family. The forewings with five closed cells, of which the first medial cell is triangular. The star claws are pectinate, the first metasomal segment is distinctively elongated, forming something similar to a petiole, and the metasomal tergites II to IV are fused as a syntergum (Figures 32-34)



Source: http://treatment.plazi.org/id/03D3879DFFD8FFB9FF0DA0564CFAFCE2

Figure 32 *Helorus alborzicus* Izadizadeh, van Achterberg & Talebi sp. nov. A. Lateral aspect of female general habitus, B. Fore wing



Source: http://treatment.plazi.org/id/03D3879DFFD8FFB9FF0DA0564CFAFCE2

Figure 33 *Helorus ruficornis* Foerster, 1856. A. Lateral aspect of male general habitus, B. Fore wing

Source: http://treatment.plazi.org/id/03D3879DFFD8FFB9FF0DA0564CFAFCE2

Figure 34 *Helorus alborzicus* Izadizadeh, van Achterberg & Talebi sp. nov. A. Dorsal aspect of head, B. dorsal aspect of mesosoma, C. Dorsal aspect of metasoma, D. Lateral aspect of metasoma

5.3 Biology

Individuals of this family are solitary, endoparasitoids of Chrysopidae (Neuroptera) larvae, and use the cocoon created by the host to complete their cycle (Figure 35) [47,48,49].

Source: https://www.galerie-insecte.org/galerie/ref-76852.htm

Figure 35 *Helorus ruficornis* Foerster, 1856. Feeding on nectar and pollinating

Helorus ruficornis Förster, 1856. Holotype in Vienna. Type locality: Germany, Aachen.

Hosts. *Chrysopa ventralis* Curtis, 1834*, Chrysopa prasina* Burmeister, 1839 (Chrysopidae; Neuroptera).

Afrotropical region: Burundi, Kenya, South Africa, Uganda. Also, the Oriental region: Korea, Pakistan (Rawalpindi), Nepal (Pulchowki); the Nearctic region: Canada, USA (including Hawaii); the Palaearctic region: Andorra, Austria, Bulgaria, Czechoslovakia, England, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Portugal, Spain, Sweden and Switzerland [50,51,52].

5.4 Taxonomy

In the Neotropical Region, only one species occurs, *Helorus brethesi* Ogloblin, 1928, distributed from Mexico to Argentina (Figure 37) [53,54].

Source: https://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=173714

Figure 36 Heloridae is a family of wasps in the order Hymenoptera known primarily from fossils, and only one extant genus, *Helorus*, with 12 species found worldwide. Members of *Helorus* are parasitic on green lacewings

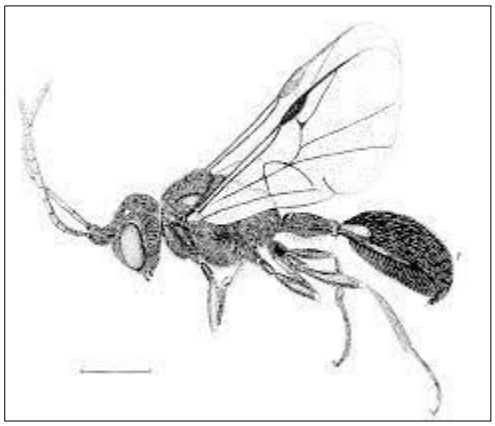
For America only three species have been reported: *Helorus brethesi* Ogloblin, 1928 (Neotropical); *Helorus ruficornis* Foerster, 1856 (Holarctic, Afrotropical) and *Helorus anomalipes* Panzer, 1798 (Holarctic) (Figures 38-41) [55,56,57].

Source: https://www.researchgate.net/figure/Specimen-of-Helorus-brethesi-collected-in-Palmeira-PR-Brazil_fig1_315081752

Figure 37 *Helorus brethesi* Ogloblin, 1928, collected in Palmeira, PR, Brazil

Source: http://www.waspweb.org/ Proctotrupoidea/Heloridae/Helorus/Helorus_ruficornis.htm

Figure 38 *Helorus ruficornis* Foerster, 1856



Sources: Drawing by A. Watsham and

https://www.researchgate.net/figure/Helorus-anomalipes-Panzer-habitus-lateral-aspect-Drawing-by-A-Watsham_fig1_254912458

Figure 39 *Helorus anomalipes* Panzer, 1798. Habitus, lateral aspect

Source: https://www.mapress.com/pe/article/view/palaeoentomology.3.4.4.

Figure 40 *Helorus arturi* sp. nov. (Hymenoptera, Proctotrupoidea, Heloridae) from Baltic amber. These analyses strongly supported the monophyly of their new concept of the superfamily Proctotrupoidea. It included seven families: Austroniidae, Heloridae, Pelecinidae, Peradeniidae, Proctotrupidae, Roproniidae and Vanhorniidae. Diapriidae and Monomachidae, formerly considered to be proctotrupoids, were placed (with other taxa) in the sister group to Proctotrupoidea *sensu stricto*. Sharkey MJ, James M. Carpenter JM, Vilhelmsen L. et al. Phylogenetic relationships among superfamilies of Hymenoptera. *Cladistics*, 28, 80–112. 10.1111/j.1096-0031.2011. 00366.x and Heraty J, Ronquist F, Carpenter JM. Et al. Evolution of the hymenopteran megaradiation. *Mol Phylogenet Evol*, 2011; 60(1), 73–88. DOI: 10.1016/j.ympev.2011.04.003

6 Selected works

6.1 Study 1

Here is presented the first record of the Heloridae family for Colombia and to the north of South America, formerly known as Argentina, Brazil and Mexico and Costa Rica.

Examined material: Female. Colombia. Quindío Genoa, Vda. El Cedral Farmca Buenos Aires Cafetal con sombrío, jama 27 Oct 1999, E. González & J. Sosa-Calvo, Leg [58,59,60].

With this finding and the information obtained from the literature, it seems that individuals of this species are found in an altitudinal range between 900 and 2500 m. His finding is equally valuable if one considers that the specimen was collected in a landscape fragmented by coffee crops. *Helorus brethesi* Oglobin, 1928 was recorded for the Neotropics [61,62].

This publication suggests that the species is found distributed from or south of Mexico to or north of Argentina and also in Brazil. The species in Costa Rica was found in 1200 houses in a humid tropical forest near the border with Panama. In the same publication, we record the presence of a possible new species collected at more than 2500 m [63].

6.2 Study 2

The present work is registered for the first time for Panama the family Heloridae and the species *Helorus brethesi* Ogloblin, 1928. Additionally, information is presented on all previous records of *H. brethesi*, the only species described with Neotropical distribution.

6.2.1 Helorus brethesi Ogloblin, 1928

Rev. Soc. Int. Argentina 1928: 77. Type: sex? Loreto, Misiones, Argentina: Examined material: Panama: Santa Fe, Alto de Piedra, Veraguas, 24-26 Mar. 1999, coll. A. Santos, L. De Gracia, Malaise trap (2,6) [64,65].

Museum of Invertebrates G. B. Fairchild, University of Panama). Costa Rica: Puntarenas, Altamira Station, 1450m, 20 Jan-Feb. 1995, coll. J. F. Quesada, Malaise trap (3, National Museum of Costa Rica); Puntarenas, Cerro Frantzius, 2134m, Sept. 29-nov. 16. 1997, coll. R. Villalobos, Malaise trap (1, National Museum of Costa Rica) [66]

Distribution: Southern Mexico, Brazil, Argentina, Costa Rica, Colombia and Panama. First record of the family and the species for Panama [66].

Habitat and ecology: These species have been previously recorded in altitudinal ranges ranging from 900 to 2,500 masl. The two specimens collected in Panama were located at 750 masl, which tells us that this species is not found in the lowlands. Specimens have been trapped in areas modified by man in Brazil (in tobacco cultivation), Colombia (in shady cafetal), Panama (secondary forest) and Costa Rich (Botanical Garden) [67].

6.3 Study 3

The proctotrupoids constitute a very diverse group but are imperfectly known. It is a fairly ancient taxon, its fossils dating from the Jurassic period. All its members develop as parasitoids of states immatures of different orders of hexapods, as well as myriapods and spiders. Due to their behavior, they are considered of interest in terms of biological control (Figure 42) [68,69].

Source: https://www.biodiversity4all.org/observations/91863029

Figure 41 Specimen of Superfamily Proctotrupoidea

biological or integrated of insects. harmful from the agricultural or health point of view. Numerous species have been used or are considered potentially usable for control in different parts of the world 70 [70].

This study deals with the families Austroniidae (including Trupochalcidinae), Diapriidae, Heloridae, Monomachidae, Pelecinidae, Peradeniidae, Proctotrupidae (= Serphidae), Roproniidae and Scelionidae [70,71].

6.3.1 Biology

All its representatives behave as immature stage parasitoids of various orders of insects, as well as spiders and myriapods. Within the superfamily Platygastroidea, scelionids act as parasitoids of insect eggs and spiders;

platygastrids of the subfamily Platygastrinae develop as parasitoids of Cecidomyiidae larvae (Diptera) and Sceliotrachelinae can attack Hemiptera aleirodoids and coccoids (Figure 43) [72].

Source: https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.2577

Figure 42 Female of *Trissolcus cultratus* (Mayr, 1879) von *Halyomorpha halys* (Stål, 1855) (Hemiptera: Pentatomidae) egg mass

In relation to the Proctotrupoidea s. str., the diaprids behave like parasitoids of preimaginal states of Diptera and Formicidae. Most of the Proctotrupidae and the Pelecinidae, are primary parasitoids of larvae of Coleoptera. The Heloridae, represented in Argentina by a single species, attack neuropteran larvae [72].

6.3.2 Diversity

The complex of proctotrupoid microhymenoptera, widely distributed in the Neotropical region, constitutes a group of great diversity, with more than 700 genera and several thousand species worldwide, but still imperfectly known.

From the superfamily Platygastroidea, they have known worldwide about 4,000 species with respect to the superfamily Proctotrupoidea s. str. about 2620 species are known; in the Argentine fauna, 46 have been recorded, corresponding to the following families: Diapriidae, Heloridae, Pelecinidae and Proctotrupidae [73,74].

7 Family Ismaridae

7.1 Introduction

Ismaridae is a family of insects belonging to the order Hymenoptera. About 50 species are known in this small relict group; all the species for which the biology is known to appear to be hyperparasitoids that parasitize Dryinidae (that attack leafhoppers) (Figure 44) [75,76].

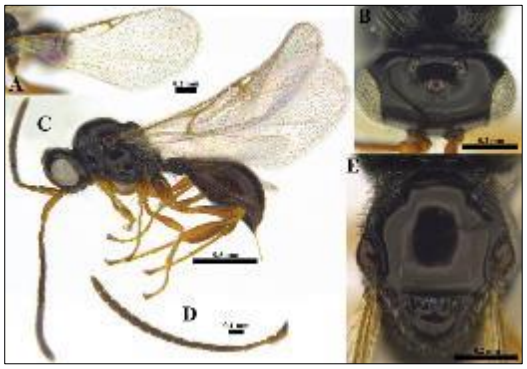
Sources: Photographs © Chang-Jun Kim (Korea National Arboretum) or © Robert Copeland (ICIPE) and http://www.waspweb.org/Diaprioidea/Ismaridae/index.htm

Figure 43 Specimen of Ismaridae Family

7.1.1 Characters

Female antenna with 15 articles and male with 14; short scape; antenna not inserted in prominent projection; mes osoma short and tall, notulix reduced; enlarged posterior tibia; 1st third of metasoma forming short petiole. Ismarids

were traditionally classified as a subfamily of Diapriidae, but molecular data have shown evidence that this is a separate family (Figure 45) [77,78,79].



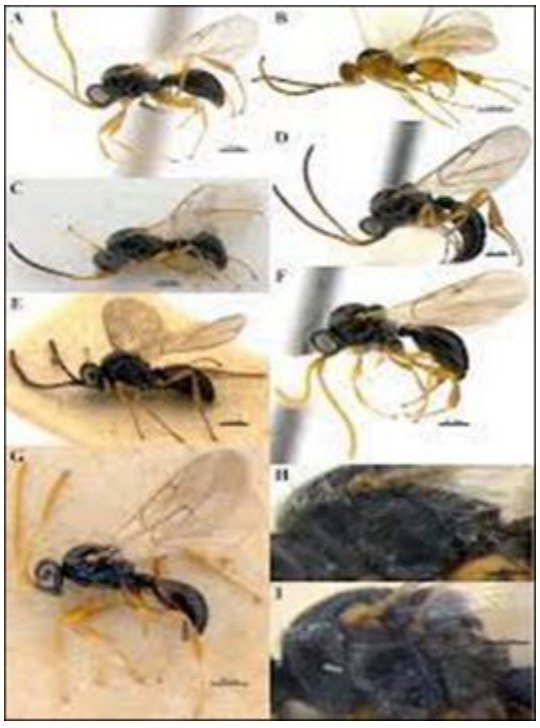
Source: https://africaninvertebrates.pensoft.net/article/24403/zoom/fig/16/

Figure 44 *Ismarus kenyensis* sp. n., female. A Fore wing B Head in dorsal view C Habitus in lateral view D Antenna E Mesosoma in dorsal view

7.1.2 Biology

The Family Ismaridae are primary parasitoids of cicadas (Hemiptera: Cicadellidae). Species of *Ismarus* act as hyperparasitoids or secondary parasitoids of larvae of Dryinidae (Hymenoptera) [80,81,82]

7.1.3 Taxonomy



Source: file:///C:/Users/USUARIO/Downloads/545-Article%20Text-2649-1-10-20180322.pdf

Figure 45 fig. 1. *Ismarus* spp., ♀♀ (A–G. Habitus; H–I. Mesosoma in lateral view). A. *Ismarus apicalis* Kolyada & Chemyreva, 2016. B. *Ismarus dorsiger* (Haliday, 1831). C, H. *Ismarus halidayi* Förster, 1850. D. *Ismarus grandis* Alekseev, 1978. E. *Ismarus rugulosus* Förster, 1850. F. *Ismarus spinalis* Kolyada & Chemyreva, 2016. G, I. *Ismarus flavicornis* (Thomson, 1858)

Ismaridae is a small family of Diaprioidea (Hymenoptera) that includes two genera: *Szelenyioprioides S*zabó, 1974 and *Ismarus* Haliday, 1835; the last one, cosmopolitan, houses 32 species, of which 12 are reported from the Neotropics and

two from Brazil*: Ismarus neotropics* Masner, 1976 and *Ismarus varicornis* Masner, 1976. Ismarids are infrequent in samples and poorly represented in entomological collections. Ismaridae is monophyletic and cosmopolitan (Figure 46) [83,84,85].

8 Studies selected

8.1 Study 1

The objective of this study was to identify the species of Ismarus that occurred in an area of Atlantic Forest in the State of São Paulo,

Brazil. Samples were collected monthly, between October 2009 and March 2011, in a dense rainforest at Intervales State Park, in Ribeirão Grande, SP. Five Malaise traps spaced about 50 m apart and active throughout the study period were used [84,85].

Three specimens of Ismarus were obtained: a female of I gracilis Masner, 1976 in October 2010 and two males of *Ismarus neotropics* Masner, 1976, in October 2009 and February 2010; the collection site has an altitude of 900 m. *Ismarus gracilis* Masner, 1976, for the first time reported for Brazil, had reported only for the localities of Chiapas, Mexico and Chiriqui, Panama, at altitudes of 2200 and 1700 m, respectively [86,87].

8.2 Study 2

8.2.1 Distribution and biology Ismaridae in Holland

Ismarus dorsiger (Haliday at Curtis, 1831)

Distribution: Palearctic species known from Europe and China. Reported in Europe from Ireland, England, Finland, Sweden, Germany, Spain and Russia.

Host: *Aphelopus atratus* (Dalman,1823) (Hymenoptera: Drynimdae) [87].

Ismarus flavicornis (Thomson, 1858)

Distribution: Holarctic species reported from Canada, the USA and Europe. Known in Europe from Ireland, England, Finland, Sweden, Switzerland, Austria, former Czechoslovakia and Italy.

Hosts: *Anteon flavicorne* (Dalman, 1818) and *Anteon jurineanum* Latreille,1809 (Hymenoptera: Drynidae) [88].

Ismarus halidayi Forster, 1850

Distribution: Holarctic species reported from Canada, the USA, China and Europe. Known in Europe by Finland, Sweden, England, Germany, former Czechoslovakia, Hungary and Russia.

Hosts: *Anteon jurineanum* (Chambers 1955) and *Anteon infectum* (Chambers 1981) (Hymenoptera: Drynidae) [89].

Ismarus rugulosus Forster, 1850

Distribution: Species reported from Canada, USA and Europe. Known in Europe from Ireland, England, Finland, Sweden, Germany, former Czechoslovakia, France, Italy and Russia.

Hosts: *Streptanus sordidus* (Zetterstedt, 1828) (Hemiptera: Cicadellidae) [90].

Ismarus dorsiger (Haliday at Curtis, 1831)

Distribution: Palearctic species are known from Europe and China. Reported in Europe from Ireland, England, Finland, Sweden, Germany, Spain and Russia.

Host: *Aphelopus atratus* (Dalman,1823) (Hymenoptera: Drynidae) [90].

Ismarus flavicornis (Thomson, 1858)

Distribution: Holarctic species reported from Canada, USA and Europe. Known in Europe from Ireland, England, Finland, Sweden, Switzerland, Austria, former Czechoslovakia and Italy.

Hosts: *Anteon flavicorne* (Dalman, 1818) and *Anteon jurineanum* Latreille,1809 (Hymenoptera: Drynidae) [90].

Ismarus halidayi Forster, 1850

Distribution: Holarctic species reported from Canada, USA, China and Europe. Known in Europe by Finland,

Sweden, England, Germany, former Czechoslovakia, Hungary and Russia.

Host: *Anteon jurineanum* (Chambers 1955) and from *Anteon infectum* (Chambers 1981) (Hymenoptera: Drynidae) [90].

Ismarus rugulosus Forster, 1850

Distribution: Holarctic species reported from Canada, the USA and Europe. Known in Europe from Ireland, England, Finland, Sweden, Germany, former Czechoslovakia, France, Italy and Russia.

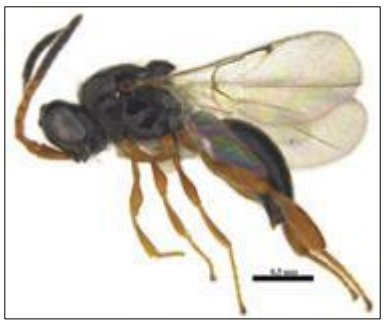
Hosts: *Streptanus sordidus* (Zetterstedt, 1828) (Hemiptera: Cicadellidae) and *Anteon pubicorne* (Dalman, 1818) [90].

8.3 Study 3

8.3.1 Ismaridae wasps of the Afrotropical region

Distribution: Botswana, Cameroon, Kenya, Madagascar, Malawi, South Africa, Uganda and Zimbabwe.

Biology: Hyperparasitoids of Cicadellidae through larvae of Dryinidae (Figures 47-51) [91].



Source: http://www.waspweb.org/Diaprioidea/Ismaridae/Ismarus/index.htm

Figure 46 *Ismarus africanus* Kim, Copeland & Notton, 2018

Source: http://www.waspweb.org/Diaprioidea/Ismaridae/Ismarus/index.htm

Figure 47 *Ismarus bicolor* Kim, Copeland & Notton, 2018

Source: http://www.waspweb.org/Diaprioidea/Ismaridae/Ismarus/index.htm

Figure 48 *Ismarus goodrichi* Kim, Copeland & Notton, 2018

Source: http://www.waspweb.org/Diaprioidea/Ismaridae/Ismarus/index.htm

Figure 49 *Ismarus kakamegensis* Kim, Copeland & Notton, 2018

Source: http://www.waspweb.org/Diaprioidea/Ismaridae/Ismarus/index.htm

Figure 50 *Ismarus rawlinsi* Kim, Copeland & Notton, 2018

8.3.2 Other Species and distribution

Ismarus halidayi Forster, 1850.

Ismarus kenyensis Kim, Copeland & Notton, 2018 (Kenya).

Ismarus laevigatus Kim, Copeland & Notton, 2018 (South Africa).

Ismarus madagascariensis Kim, Copeland & Notton, 2018 (Madagascar).

Ismarus minutus Kim, Copeland & Notton, 2018 (Kenya, Malawi, Zimbabwe).

Ismarus nigrofasciatus Kim, Copeland & Notton, 2018 (Malawi, Uganda).

Ismarus notaulicus Kim, Copeland & Notton, 2018 (Kenya).

Ismarus steineri Kim, Copeland & Notton, 2018 (Madagascar).

Ismarus watshami Kim, Copeland & Notton, 2018 (Botswana, Malawi, South Africa, Zimbabwe) [91].

9 Conclusion

The methodological basis of this work consists of bibliographical research of scientific articles published in academic scientific journals. The search criterion for the articles was to prioritize articles that dealt with the theme of the Ismaridae Family. Document analysis was used as a data collection method to gather information.

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