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Study of the bionomy of the Ichneumonidae Family (Insecta: Hymenoptera)

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Abstract

They are ecto- or endoparasitoids of other arthropods, especially of the larvae and pupae of beetles (Coleoptera), wasps, bees and ants (Hymenoptera) and of moths and pollen (Lepidoptera). Because of this they are a very important group as biological control of pest. The aim of this manuscript was to carry out an inventory of the Ichneumonidae Family (Insecta: Hymenoptera) related to its biogeography, bioecology, habitat, geographic distribution, taxonomy, life cycle, phenology and taxonomic and conceptual aspects of the Family, Subfamilies and Species. To this end, a bibliographic survey of Ichneumonidae was carried out in the years 1937 to 2021. Only complete articles published in scientific journals and expanded abstracts presented at national and international scientific events, Doctoral Thesis and Master's Dissertation were considered. Data were also obtained from platforms such as: Academia.edu, Frontiers, Qeios, Pubmed, Biological Abstract, Publons, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science and ERIC.

Keywords: Parasitism; Lepidoptera; Coleoptera; Biodiversity; Parasitoid

1. Introduction

1.1. Description

The icneumónidos (Ichneumonidae) are a family of apocrytic hymenoptera with more than 60,000 species distributed all over the world. It is the richest family in species of Hymenoptera with a worldwide distribution. Its size is very diverse, usually between 2-20 mm in length (Figure 1) [1,2].

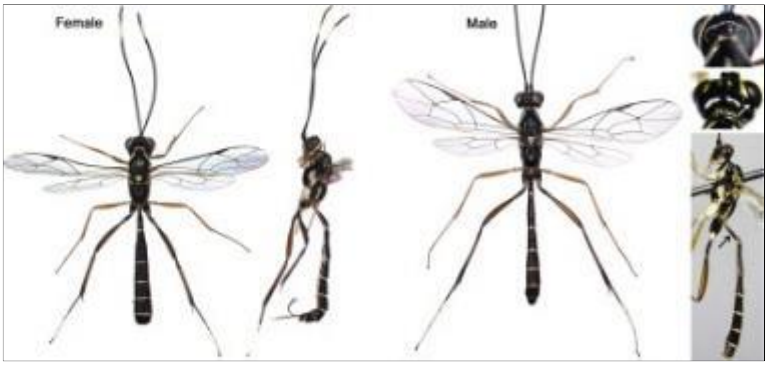

Figure 1 Ichneumonidae specimens: Female and Male; (Source: https://www.sciencedirect.com/science/article/abs/pii/S1226861513001027)

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1.2. Ichneumonid Morphology

The morphological terminology is mostly that of Townes (1969). The following treatments of Hymenoptera morphology are recommended to the interested student: Michener (1944), Bohart & Menke (1976), and Huber & Sharkey (in: Goulet & Huber, 1993) (Figures 2, 3, 4 and 5).

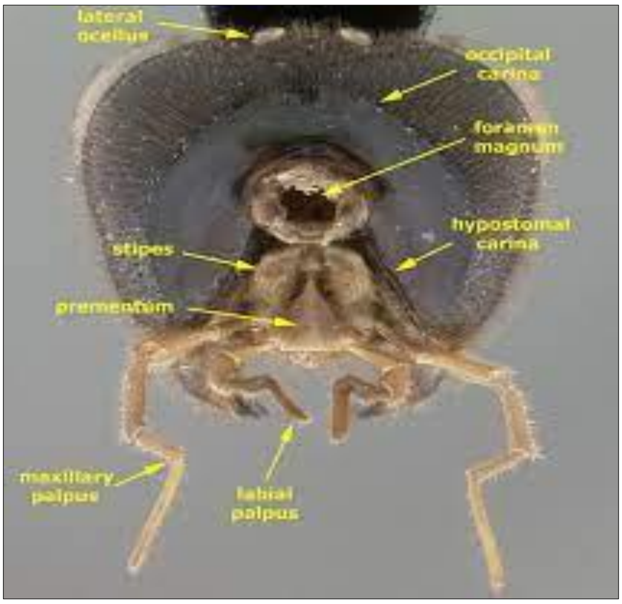


Figure 2 Head of an ichneumonid posterior view showing mouthparts; (Source: http://www.amentinst.org/GIN/morphology.php)

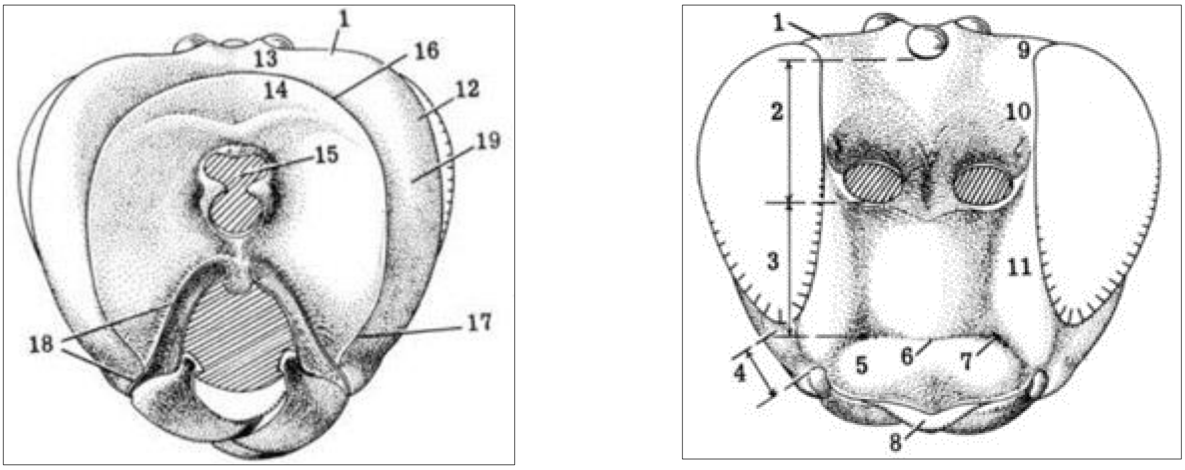


Figure 3 Head of an ichneumonid, previous and posterior views: 1, 13. Vertex, 2. Supra-antennal area; 3. Supraclypeal area; 4. Malar space (= cheek); 5. Clypeus; 6. Groove between face and clypeus; 7. Anterior tentorial pit (= clypeal fovea); 8. Labrum 9, 10, 11. Paraocular área; 12. Genal orbit; 14. Occiput; 15. Foramen magnum; 16, 17. Occipital carina (17 = Genal carina) 18. Hypostomal carina (= oral carina) 19. Genal (= temple); (Source: http://www.amentinst.org/GIN/morphology.php)

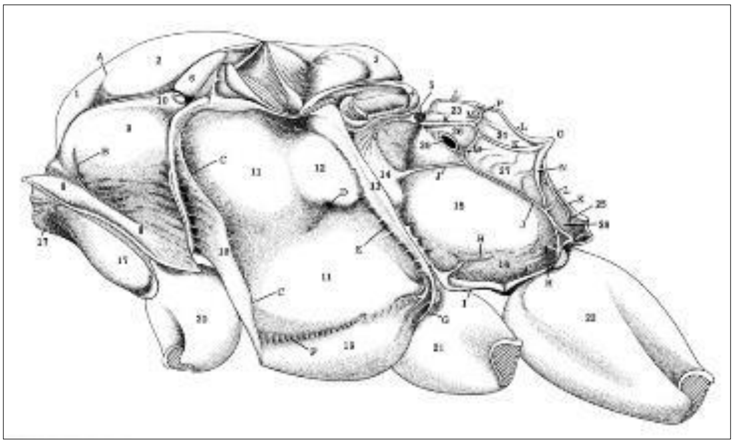


Figure 4 Mesosoma of an ichneumonid, lateral view:1. Median lobe of mesoscutum; 2. Lateral lobe of mesoscutum;1, 2. Mesoscutum; 3. Scutellum; 4. Metanotum (= postscutellum); 5. Hind margin of methanotum; 6. Tegula; 7. Subtalar ridge (= subtegular ridge); 8. Collar 8, 9, 10. Pronotum; 10. Hind corner of pronotum; 11, 12, 13, 18, 19. Mesopleuron; 11, 12, 18, 19. Mesepisternum; 12. Hypoepimeron (=speculum); 13. Mesepimeron; 14. Dorsal division of metapleuron; 15. Ventral division of metapleuron; 16. Juxtacoxal area; 17. Propleuron; 18. Epicnecium (= prepectus); 19. Mesothoracic venter; 20. Fore thigh; 21. Middle thigh; 22. Hind thigh; 23-28. Propodeum; 23. First lateral area; 24. Second lateral area; 25. Third lateral area; 26. First pleural area 27. Second pleural area; 28. Third pleural area; 29. Propodeal spiracle. Carinae, grooves & propodeal areas:

A. Notaulus; B. Epomy; C. Epicnemial carina (= prepectal carina); D. Scrobe (= Mesopleuron fovea); E. Mesopleural groove; F. Sternaulus; G. Posterior transverse carina of mesothoracic venter; H. Juxtacoxal carina; I. Submittal pleural carina; J. Pleural carina K. Lateral longitudinal carina of Propodeum; L. Median longitudinal carina of propodeum; M. Anterior transverse carina of propodeum (= basal transverse carina); N. Posterior transverse carina of propodeum (= anterior transverse carina); O. Propodeal apophysis or crest; P. Costula [part of anterior transverse carina]; (Source http://www.amentinst.org/GIN/morphology.php)

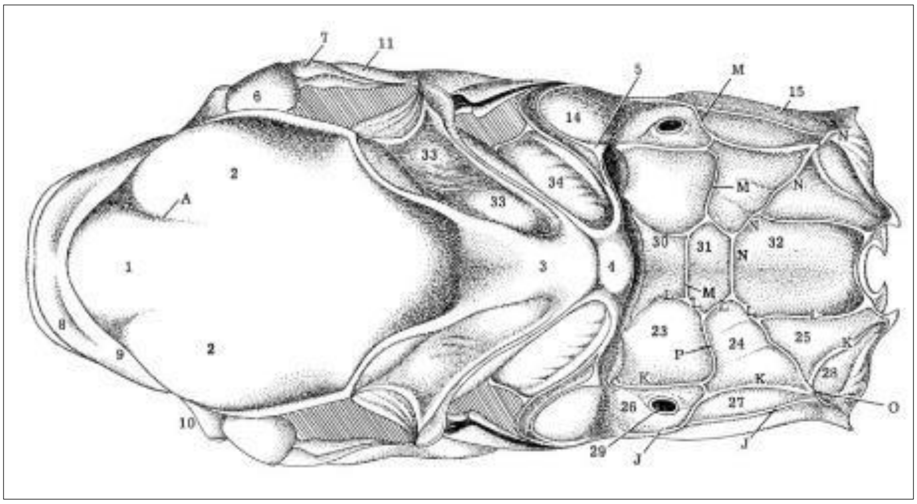
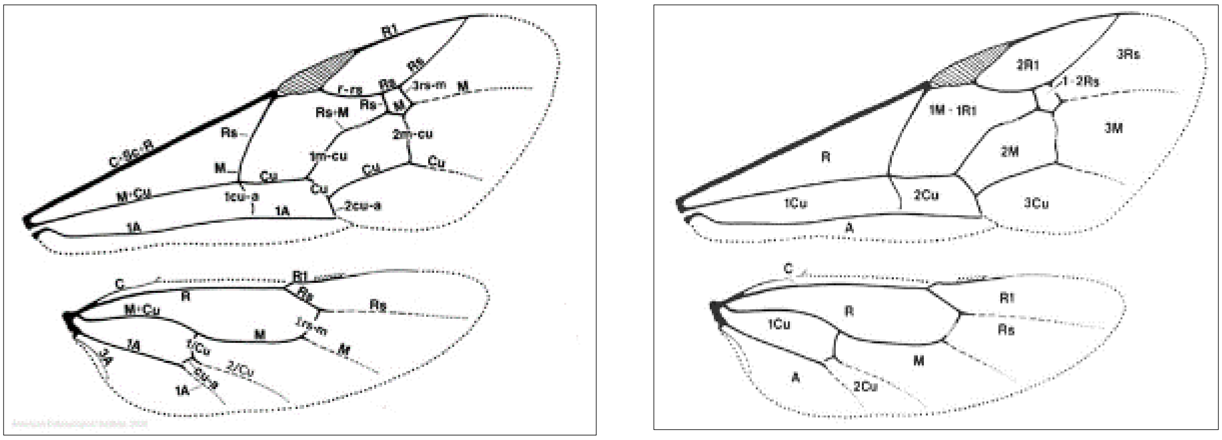


Figure 5 Mesosoma of an ichneumonid, dorsal view: 1. Median lobe of mesoscutum; 2. Lateral lobe of mesoscutum; 1, 2. Mesoscutum; 3. Scutellum; 4. Postcutellum; 5. Hind margin of methanotum; 6. Tegula; 7. Subtalar ridge (= subtegular ridge) 8. Collar; 8, 9, 10. Pronotum; 10. Dorsolateral corner of pronotum; 11. Mesopleuron [mesepisternum]; 14. Dorsal division of metapleuron; 15. Ventral division of metapleuron 23-32. Propodeum; 23. First lateral area; 24. Second lateral area; 25. Third lateral area; 26. First pleural area; 27. Second pleural area; 28. Third pleural area; 29. Propodeal spiracle; 30. Basal area; 31. Areola; 32. Petiolar area; 33. Axillary trough of mesonotum; 34. Axillary trough of methanotum; Carinae, grooves & propodeal areas:

J. Pleural carina; K. Longitudinal lateral carina of propodeum; L. Median longitudinal carina of propodeum; M. Anterior transverse carina of propodeum (= basal transverse carina); N. Posterior transverse carina of propodeum (= anterior transverse carina); O. Propodeal apophysis or crest; P. Costula [part of anterior transverse carina; (Source: Source http://www.amentinst.org/GIN/morphology.php)

They differ from other similar hymenoptera, especially from the Braconidae family, by the presence in the anterior wings of the transverse veins 1st and 2nd recurrent (2m-cu) and the absence of the vein 1/Rs+M which originates a large 1M + 1R1 cell, the costal cell, below the anterior half of the pterostigma (Figures, 6A, 6B, 7, 8, 9, 10A and 10B [1,2,3].



A B

Figure 6 A Fore and hind wings of an ichneumonid (Ross system veins). Figure 6B Fore and hind wings of an ichneumonid (Ross system wing cells); (Source: Source http://www.amentinst.org/GIN/morphology.php)

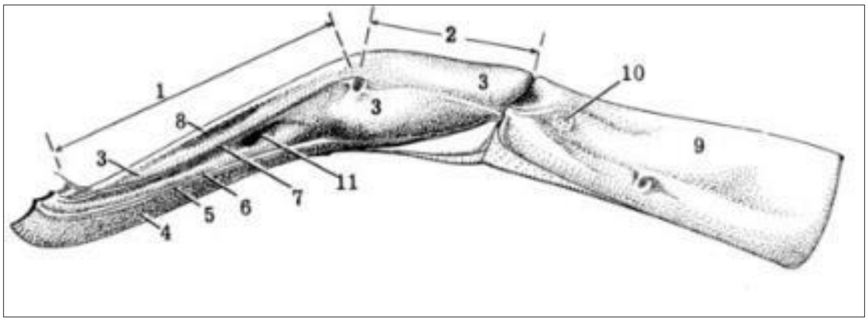


Figure 7 First and second metasomal segments, lateral view: 1. Petiole; 2. Postpetiole; 3. Tergite 1; 4. Sternite 1; 5. Tergosternal suture; 6. Ventrolateral carina 7. Dorsolateral carina; 8. Median dorsal carina; 9. Tergite 2; 10. Thyridium; 11. Glymma; (Source http://www.amentinst.org/GIN/morphology.php)

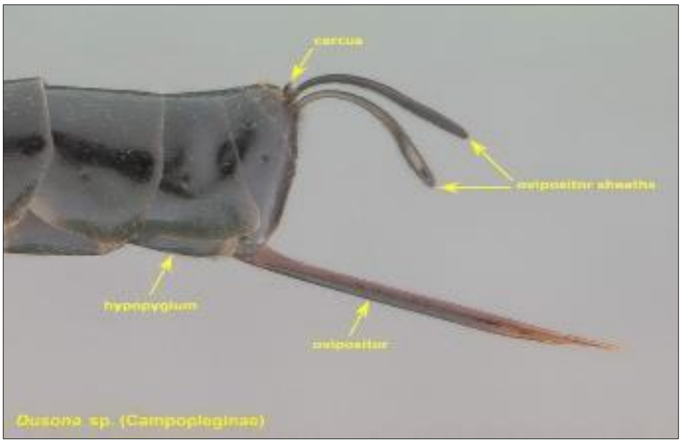


Figure 8 Posterior region of female metasoma, lateral view; (Source http://www.amentinst.org/GIN/morphology.php)

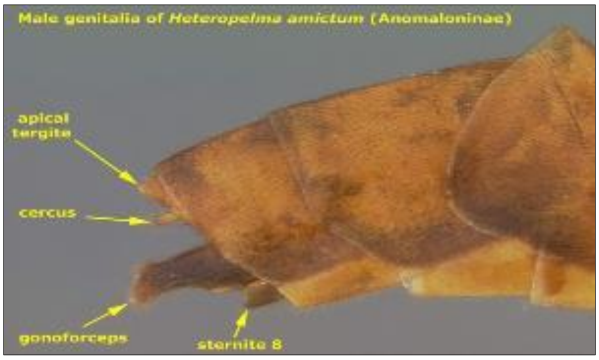
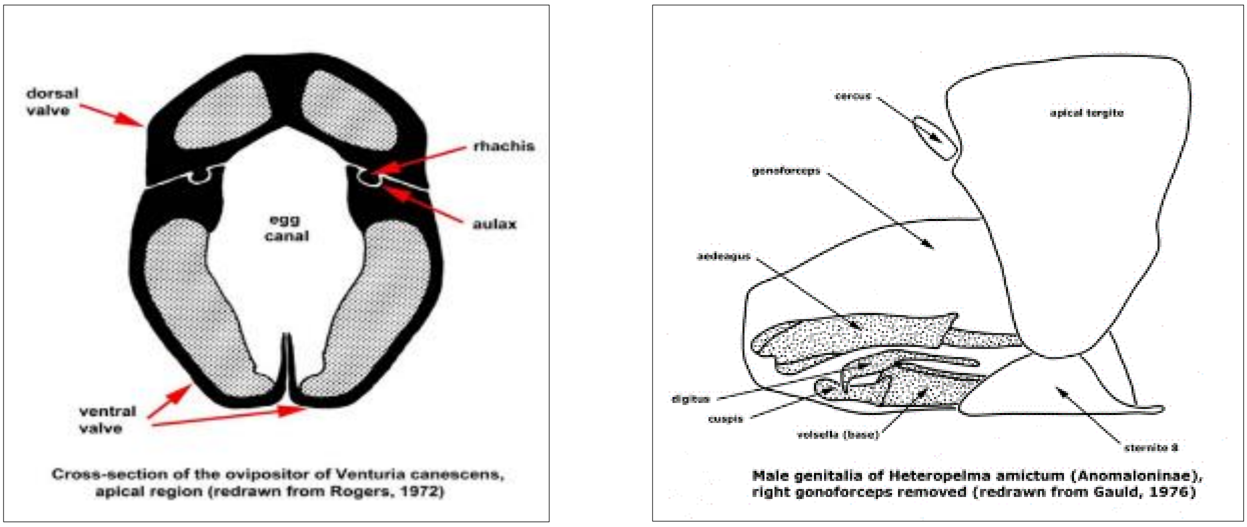


Figure 9 Ichneumonid male genitalia; (Source http://www.amentinst.org/GIN/morphology.php)



A B

Figure 10 A Ichneumonid ovipositor, cross-section. Figure 10B Male genitalia; (Source (Gauld ID. The classification of the Anomaloninae (Hymenoptera: Ichneumonidae. Bulletin of the British Museum (Natural History), Entomology. 1976; 33: 1-135)

1.3. Life cycle

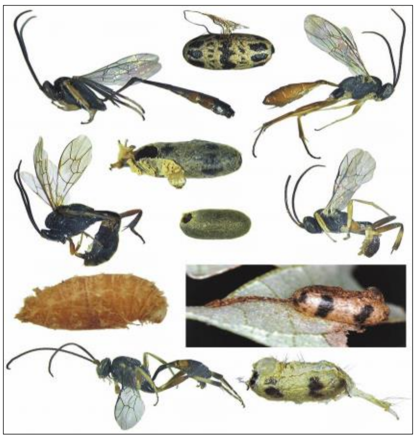


Figure 11 21. Ichneumonidae: Campopleginae. 11-12, *Charops* sp.; 11, bad habit; 12, cocoon. 13-15, *Hyposoter* sp. 1 13, female, habit; 14–15, cocoon under host remains (Geometridae: *Semaopus* sp.); 16-17, *Hyposoter* sp. 2; 16, a bad habit; 17, cocoon. 18-19, *Microcharops longiterebra* Gupta, 1987; 18, a bad habit; 19, mummified caterpillar remains (Limacodidae sp. 3). 20-21, *Microcharops* sp.; 20, a bad habit; 21, cocoon under host remains (Noctuidae*: Bagisara paulensis* Schaus 1898). Scale bar: 1 mm

They are ecto- or endoparasitoids of other arthropods, especially of the larvae and pupae of beetles (Coleoptera), wasps, bees and ants (Hymenoptera) and of moths and pollen (Lepidoptera). Because of this they are a very important group as biological control of pest. The human for each species is very specific in some cases and in others. There is a symbiotic relationship with a polydnavirus that infect its human being and prevents it from rejection the parasitoid. 3 The majority of the winter as adults, generally under the bark of fallen trees. 4 Adults feed on a variety of sources, including nectar, millet spray, other insects and a human hemolymph when depositing the seeds (Figures 11, 12, 13 and 14) [1,2,3,4].

Figure 12 Pupa belonging to the *M. alcon "pneumonanthe"* ecotype parasitised by *Ichneumon balteatus* Wesmael, 1845; (Source: https://www.researchgate.net/figure/Pupa-belonging-to-the-M-alcon-pneumonanthe-ecotype-parasitised-by-Ichneumon_fig2_280482546)

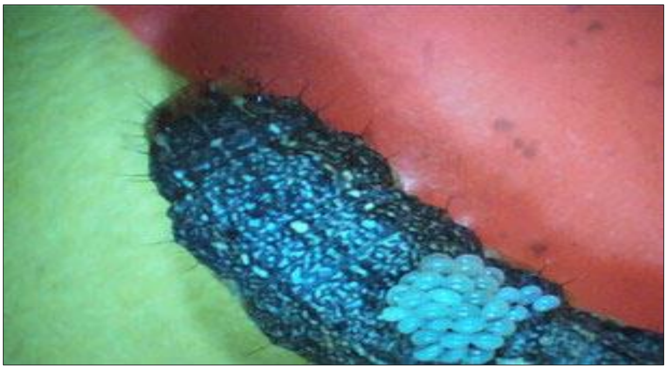


Figure 13 Eggs of Ichneumonidae; (Source: http://www.omafra.gov.on.ca/IPM/english/apples/beneficials/braconid-wasps.html)

Figure 14 Egg of Ichneumonidae; (Source: https://bugguide.net/node/view/20332/bgimage)

1.4. Oviposition

Some species of ichneumonids can be found in their bodies but in the majority of people inject directly into the body of the human being. In some species, especially in the *Megarhyssa* and *Rhyssa* genera, both sexes circulates on tree trunks, repeatedly touching the surface with their antennae. For different reasons, the fertilized female tries to find the larvae of wood, for example, those of the Siricidae family of hymenoptera, in which she will deposit her eggs. The males are looking for the females to come out of their pupae with which they mate (Figures 15 and 16) [5,6,7,8].

Figure 15 An ichneumon wasp Megarhyssa boring wood and depositing an egg into a tunnel in deadwood bored by its host, the larva of a large species of horntail; (Source: https://www.dreamstime.com/ichneumon-wasp-megarhyssa-boring-wood-depositing-egg-tunnel-deadwood-bored-its-host-ichneumon-wasp-image200140171)

Figure 16 This *Ichneumon* Wasp has black body with white spots. The legs are orange and the antenna are black with a broad white band. Females have a long ovipositor egg laying tube that is longer than the body. The male does not have an ovipositor body length 15mm The female lays an egg in a caterpillar. When the egg hatches the wasp larva feeds on the caterpillar; (Source: https://www.dreamstime.com/ichneumon-wasp-has-black-body-white-spots-legs-orange-antenna-black-broad-white-band-females-image182632275)

When the female perceives the vibrations of a chattering insect that will serve as a human being for her offspring, she perforate the wood with her ovipositor until reaching the cavity where the human is located. She then injects an egg with her hollow ovipositor inside her victim's body. It is still unknown how it can cut wood, but it is known that there are metals (manganese or ionized) in the extreme of the ovipositor of some species (Figure 17) [9,10,11,12,13].

Oviposition process in *Dolichomitus imperator* (Kriechbaumer, 1854). Oviposition phases:

- Feeling with the antennae, the wasp perceives the vibrations that indicate the presence of a possible host.
- With its long ovipositor, the wasp drills a hole through the bark.
- The wasp inserts the ovipositor into the cavity containing the host's larvae.
- 4 Making adjustments.
- By laying their eggs, the ovipositor can be seen embedded in the wood and its protective cover lifted upwards.
- 6, Laying their eggs.

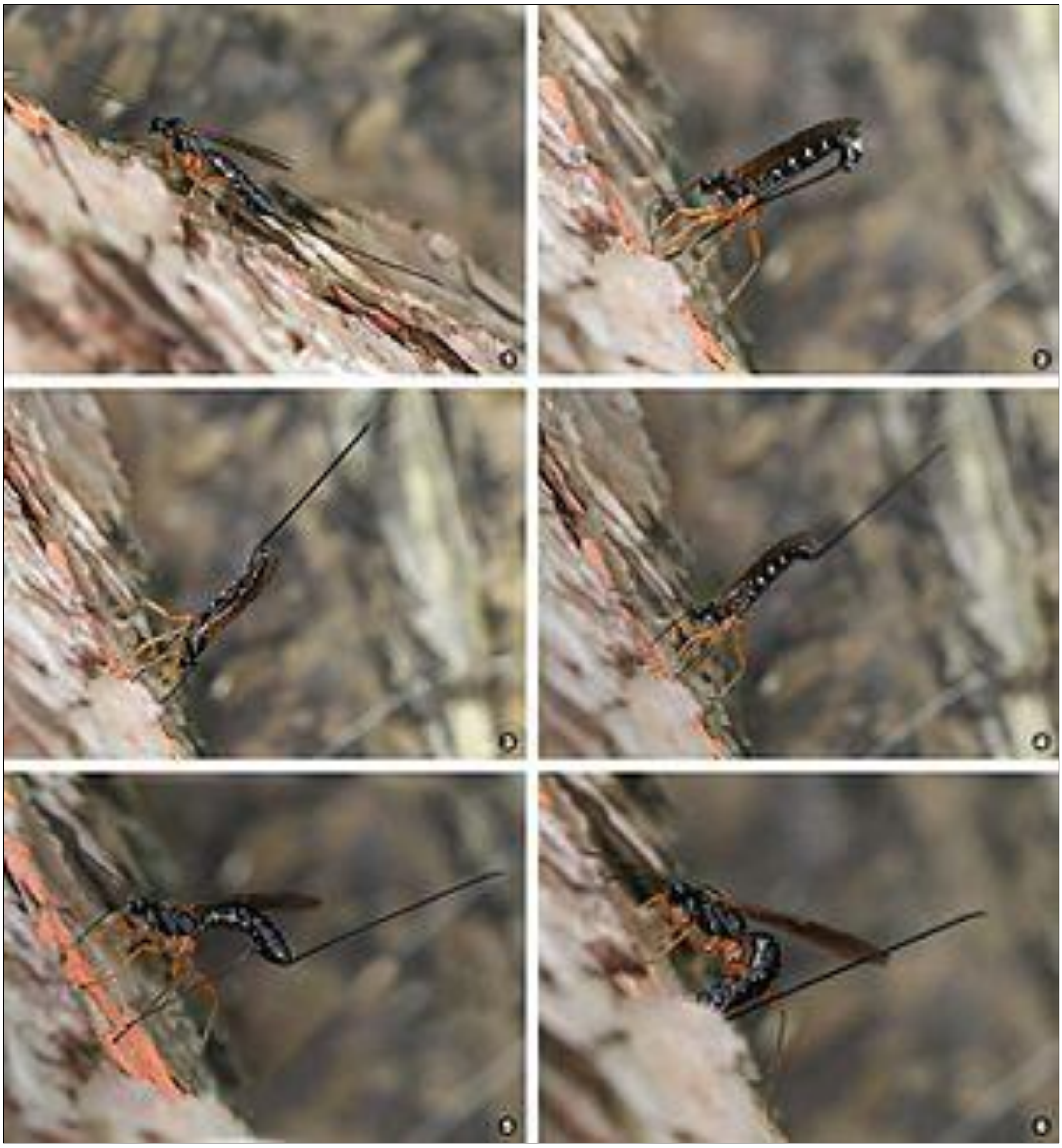


Figure 17 Oviposition process in *Dolichomitus imperator* (Kriechbaumer, 1854). 1. Feeling with the antennae, the wasp perceives the vibrations that indicate the presence of a possible host. 2. With its long ovipositor, the wasp drills a hole through the bark. 3. The wasp inserts the ovipositor into the cavity containing the host's larvae. 4 Making adjustments. 5. By laying their eggs, the ovipositor can be seen embedded in the wood and its protective cover lifted upwards. 6, Laying their eggs. *Hercus fontinalis* (Holmgren, 1857) life cycle; (Source: https://en.wikipedia.org/wiki/Ichneumonidae)

1.5. Distribution

They are found on all continents except Antarctica. They inhabit every class of terrestrial habitats where there are Adequate guests. The distribution of its biodiversity has given rise to discussion. It is believed that they broke the rule that there is greater biodiversity in tropical climates, the so-called latitudinal gradient of diversity [12,13,14].

1.6. Taxonomy and systematics

1.6.1. Ophion luteus L., 1758, (Ophioninae).

Diplazon cf laetatorius newly emerged from a puparium of Syrphidae fossil icneumonid in Dominican amber from 15 to 20 million years ago The icneumónidos have been and continue to be a taxonomic problem. They are an extremely varied group with many small species, difficult to identify and that go easily unnoticed. With great diversity, only the

DNA sequences of a very low percentage of species have been analyzed and the detailed cladistic studies require large-scale competition (Figure 18).

Figure 18 An ichneumonid caught in amber 15-20 million years ago; (Source: https://en.wikipedia.org/wiki/Ichneumonidae)

As well, there is a good number of seminal works, including the extensive study and catalog of synonym of Townes, as well as the work of other Entomologist, especially J. F. Aubert, which has an excellent collection of ichneumonids from Lausanne [15,16,17].

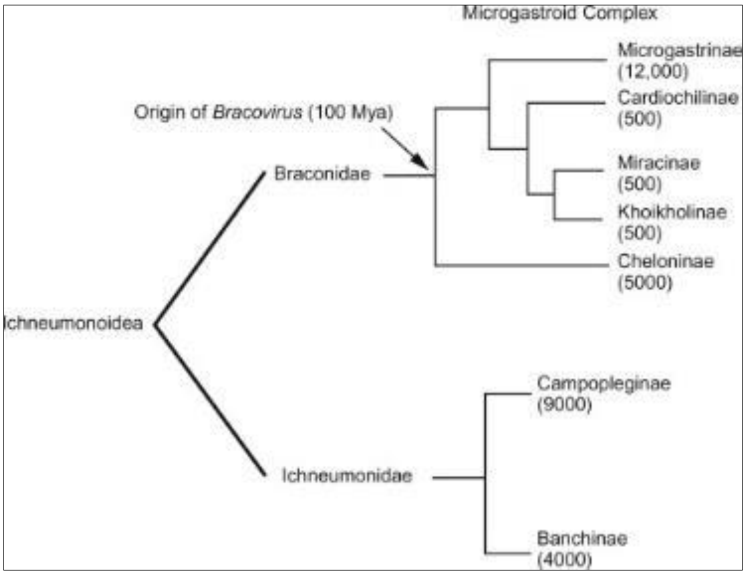


Figure 19 Bracovirus and ichnovirus phylogenetic tree illustrating that all members of the Polydnaviridae are associated with parasitoid wasps in the superfamily Ichneumonoidea. Subfamilies of the Braconidae that carry bracoviruses and subfamilies of the Ichneumonidae that carry ichnoviruses are shown. Parentheses indicate the approximate number of wasp species in each subfamily; (Source: https://www.sciencedirect.com/topics/immunology-and-microbiology/ichneumonoidea)

1.7. Subfamilies

1.7.1. Ichneumon ultimus Cresson 1877 female (subfamily Ichneumoninae)

The list below follows the suggestions of David Wahl of the American Entomological Institute.13 It will need to continue to be updated as new research resolves the interconnections between ichneumonids. The subfamilies are not listed in taxonomic or phylogenetic sequence, since these relationships are not fully resolved and such an organization would be of no value:

Acaenitinae, Agriotypinae, Adelognathinae, Anomaloninae (= Anomalinae), Banchinae, Brachycyrtinae (sometimes included in Labiinae), Campopleginae (= Porizontinae), Collyriinae, Cremastinae, Cryptinae (= Gelinae, Hemitelinae, Phygadeuontinae), Ctenopelmatinae (= Scolobatinae), Cylloceriinae (= Oxytorinae, sometimes included in Microleptinae), Diacritinae (sometimes included in Pimplinae), Diplazontinae, Eucerotinae (sometimes included in Tryphoninae), Ichneumoninae, Labeninae (= Labiinae), Lycorininae (sometimes included in Banchinae), Mesochorinae, Metopiinae, Microleptin, Neorhacodinae (sometimes included in Banchinae), Ophioninae, Orthocentrinae (sometimes included in Microleptine), Orthopelmatinae, Oxytorinae, Paxylommatinae (sometimes not even in Ichneumonidae), Pedunculinae, Phrudinae, Pimplinae (= Ephialtinae), Poemeniinae (sometimes included in Pimplinae), Rhyssinae, (sometimes included in Pimplinae), Stilbopinae (sometimes included in Banchinae), Tatogastrinae (sometimes included, in Microleptinae or Oxytorinae), Tersilochinae, Tryphoninae and Xoridinae (Figure 20) [16,17,18,19,20].

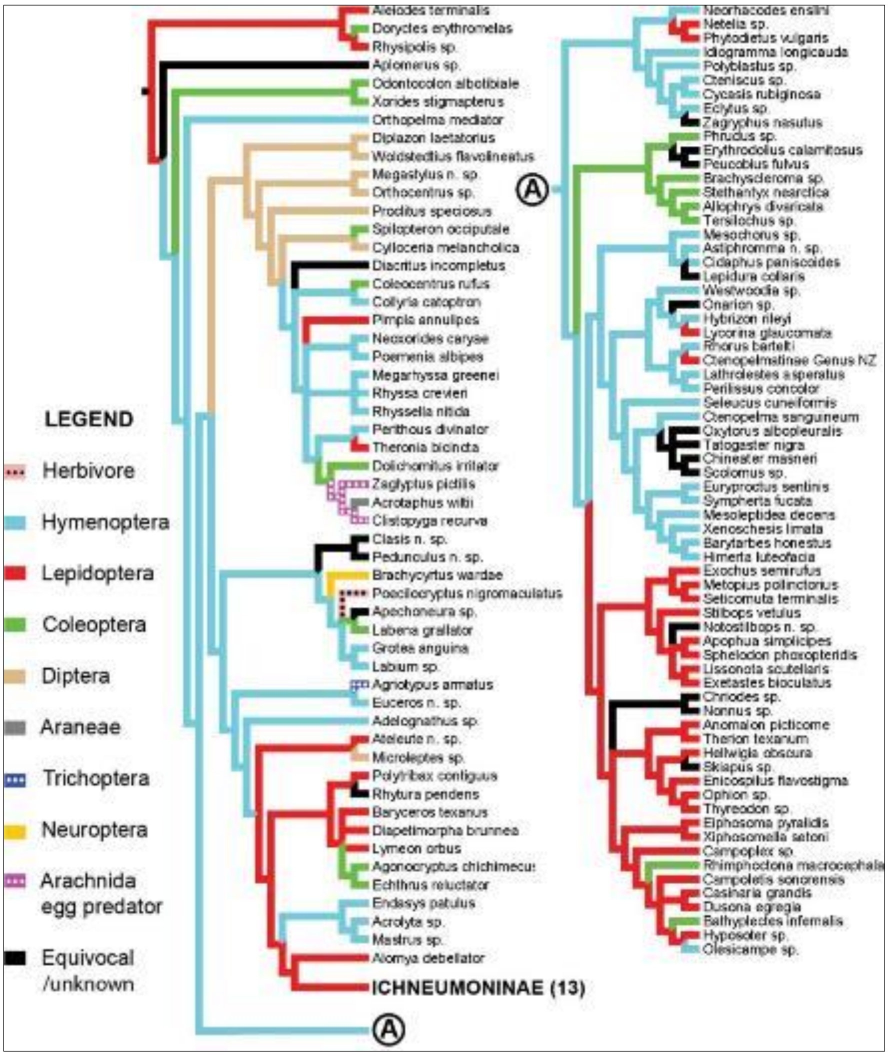


Figure 20 Phylogeny of the subfamilies of Ichneumonidae (Hymenoptera); (Source: https://jhr.pensoft.net/article/32375/zoom/fig/149/)

Objective

The aim of this article is to meet the bionomy, bioecology and biogeography of the Tenthredinidae family will be studied (Insecta: Diptera).

2. Methods

The method used to prepare this mini review was Marchiori 2021 methodology [20].

3. Studies conducted and selected

3.1. Study 1

3.1.1. Reproduction

Ichneumonids use both idiobiont and koinobiont strategies. Idiobionts paralyze their host and prevent it from moving or growing. Koinobionts allow their host to continue to grow and develop. In both strategies, the host typically dies after some weeks, after which the ichneumonid larva emerges and pupates [22,23,24].

A very few ichneumonid species lay their eggs in the ground, but the vast majority inject eggs either directly into their host's body or onto its surface, and this may require penetration of substrate around the host, as in wood-boring host larvae that live deep inside of tree trunks, requiring the ichneumon to drill its ovipositor through several centimeters of solid wood [22,23,24].

3.1.2. Hosts

Figure 21 Larva of *Acrodactyla quadrisculpta* (Gravenhorst, 1820) parasitising spider; (Source: JMDN and Bárbol)

Figure 22 Campopleginae pupa, with empty skin of caterpillar it parasitised. Cocoon (pupa) of an ichneumonid wasp attached to the underside of a leaf. And next to it, the empty skin of the caterpillar it had parasitized; (Source: JMDN and Bárbol)

The most common hosts are larvae or pupae of Lepidoptera, Coleoptera and Hymenoptera. Some species in the subfamily Pimplinae also parasitise spiders. Hyperparasitoids such as Mesochorinae oviposit inside the larvae of other ichneumonoids (Figures 21, 22, 23 and 24) [22,23,24].

Figure 23 Ichneumonid wasp, *Hercus fontinalis* (Holmgren, 1857), larvae (intermediate instar) on caterpillar. Size: ~ 3-4 mm. Pennypack Restoration Trust, Montgomery County, Pennsylvania, USA; (Source: https://bugguide.net/node/view/421737)

Figure 24 *Megarhyssa* wasp at work drilling into a tree; (Source: https://www.canr.msu.edu/news/megarhyssa_wasps)

The ovipositor (the bit that looks like a stinger) is for laying eggs not stinging people. The long flexible ovipositor is used to drill deep into dead or dying trees to deposit an egg into the body of a wood wasp or horntail larva. When the egg hatches, the *Megarhyssa* larva eats the horntail larva from within (Figures 25, 26, 27 and 28) [22,23,24].

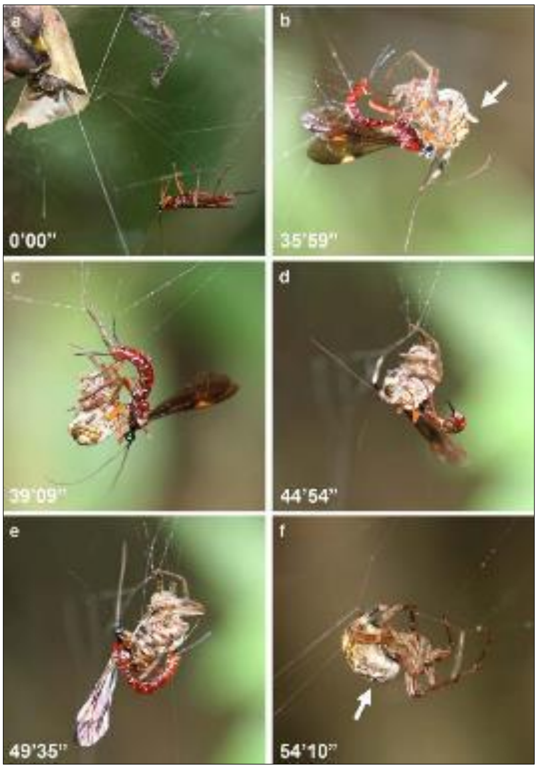


Figure 25 Parasitoid-induced mortality of *Araneus omnicolor* (Keyserling, 1893) (Araneae, Araneidae) by *Hymenoepimecis* sp. (Hymenoptera, Ichneumonidae) in southeastern Brazil; (Source: Gonzaga, M.O., Sobczak, J.F. Parasitoid-induced mortality of *A. omnicolor* by *Hymenoepimecis* sp. (Hymenoptera, Ichneumonidae) in southeastern Brazil. Naturwissenschaften. 2007; 94: 223–227)

Figure 26 A Tomato Hornworm with wasp eggs. A wasp has injected her eggs into this hornworm. When the eggs hatch into larvae, the caterpillar will be eaten; (Source: https://www.istockphoto.com/br/foto/vespa-parasit%C3%B3ide-da-lagarta-de-tomate-com-ovos-gm93242227-1760654)

Figure 27 Campopleginae parasitoid wasps (Campopleginae parasitoid wasps) immature(s); (Source: Ansel Oommen, Bugwood.org)

Figure 28 Genera *Ichneumonorum* Nearcticae; (Source: http://www.amentinst.org/GIN/)

3.2. Study 2

Thus, the objectives of this study were: to carry out a survey of subfamilies of Ichneumonidae and, whenpossible, of its genus present in three areas of Caatinga biome at different levels of anthropogenic degradation; register to occurrence of genera and/or species and compare the effectiveness of sampling in capturing the richness of subfamilies among the areas studied [25].

Malaise trap was placed in three caatinga fragments in the Jequié region, Bahia, namely: area 1 border of pasture (BP) W); area 2 Agroecosystem (AE) - located in the District of Irritation, Area 3 Caatinga Remnant (RC) – in a fragment apparently with less anthropic alteration (Figures 29, 30, 31A and 31B) ([25].

1,087 specimens of Ichneumonidae were obtained belonging to 17 subfamilies in the three sampled areas. At the RA had the smallest number of subfamilies (15); Lycorinine was exclusive to this environment and there was no occurrence of specimens of Anomaloninae and Tersilochinae there. At other subfamilies occurred in the three environments studied. The environment with the highest number of specimens collected was the RC (494 copies/45.4% of the total), followed by AR (399/36.8%) and BP (194/17.8%) [25].

Figure 29 Malaise trap; (Source: https://malaiseprogram.com/discover/what-is-a-malaise-trap/)

Figure 30 Caatinga biome; (Source: https://www.brasildefato.com.br/2021/06/10/apenas-2-do-territorio-da-caatinga-e-ocupado-por-areas-de-conservacao)

Figure 31 A Specimen of the Lycorinine; (Source: http://www.amentinst.org/GIN/Lycorininae/lycorinine.php)

Cremastinae was the most collected subfamily in RA and RC while Cryptinae 0 was in BP. In BP, three samples were taken more than in RC and five more than in AR. even with bigger number of collections, BP was the environment with the lowest number of specimens collected. Cremastinae and Cryptinae were the most numerous subfamilies in the three areas studied and, together, represented 50.6% of the collected material (551 copies), followed by Campopleginae (157/14.4%) and Phygadeuontinae (114/10.5%).

Figure 31 B Specimens the of Subfamily Cremastinae; (Source: http://treatment.plazi.org/id/D51887D3553173001ECDFECC77C16231)

Such subfamilies represented more than 75% of the specimens collected in the three environments. This fact was probably due to the greater availability of hosts. The diversity of subfamilies was quite similar in the areas sampled, which can be verified through the curves of rarefaction that demonstrated a trend of stabilization of asymptotes despite the number of samples be different in each of the sampled areas (31 in AE, 33 in RC and 36 in BP). In this way, it is verified that the number of samplings carried out in each area was enough to represent the subfamilies present in each environment.

Eight subfamilies of Ichneumonidae were, for the first time, registered for the state of Bahia: Anomaloninae, Banchinae, Lycorininae, Metopiinae, Orthocentrinae, Phygadeuontinae and Tersilochinae. In this study, 31 genera of Ichneumonidae were recognized, of which 23 for the first time registered for Bahia. The genus *Brachycyrtus, Charops, Eiphosoma, Mesochorus, Labena, Enicospilus, Neotheronia* and *Netelia* have reports of occurrence prior to the state. Records of new occurrences of subfamilies and genera of Ichneumonidae to the state of Bahia [25].

3.3. Study 3

3.3.1. Pupal parasitoid

Banded Caterpillar Parasite

Ichneumon promissorius (Erichson, 1842)
Banded caterpillar parasite (*Ichneumon promissorius* (Erichson) 1842) *Ichneumon i*s a pupal parasitoid of *Helicoverpa* and some armyworm. It is a medium-sized (14 mm) wasp, predominantly black, with orange and white markings (Figures 32, 33, 34, 35, 36 and 37) [26].

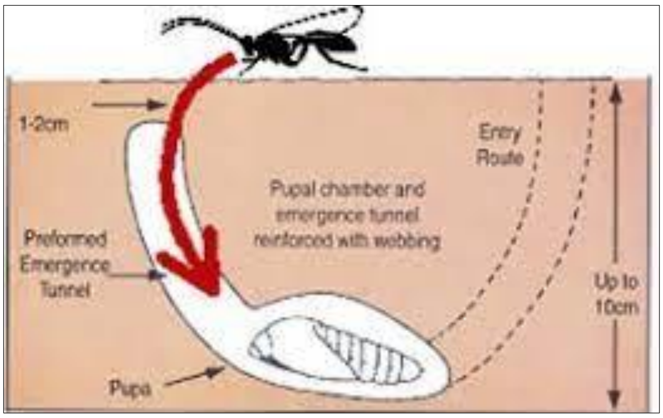


Figure 32 Pupal chamber of a *Helicoverpa* pupa. The performed emergence tunnel was made by the *Helicoverpa* caterpillar to assist its emergence as an adult moth. However, this tunnel is also used by searching Ichneumon females to gain access to host pupae; (Source: https://www.daf.qld.gov.au/__data/assets/pdf_file/0003/64677/Insect-Parasitoids-Natural-enemies-helicoverpa.pdf)

Figure 33 The life cycle of *Helicoverpa*. (a) Adult moth; (b) eggs; (c) larva and (d) pupa

*Ichneumon i*s less commonly seen in crops than *Heteropelma*, perhaps because it spends most of its time flying close to the soil surface. Ichneumon wasps are active in all summer crops. Ichneumon does not diapause with its host, and so is generally active throughout winter. Unlike other wasps, Ichneumon is active in chickpea crops.

3.4. Larval-pupal parasitoids

3.4.1. Two-toned Caterpillar Parasite

Heteropelma scaposum (Morley, 1913)

Heteropelma scaposum is a medium-sized (20 mm), slender, black wasp with an orange abdomen, yellow legs and clear wings. You may see Heteropelma flying above sorghum, cotton and other summer crops in summer. Like *Microplitis*, *Heteropelma* carries ascovirus. *Heteropelma* parasitises both *Helicoverpa* and armyworm caterpillars [26],

Figure 34 *Heteropelma scaposum* (Morley, 1913); (Source: https://davesgarden.com/guides/bf/showimage/13234/#b)

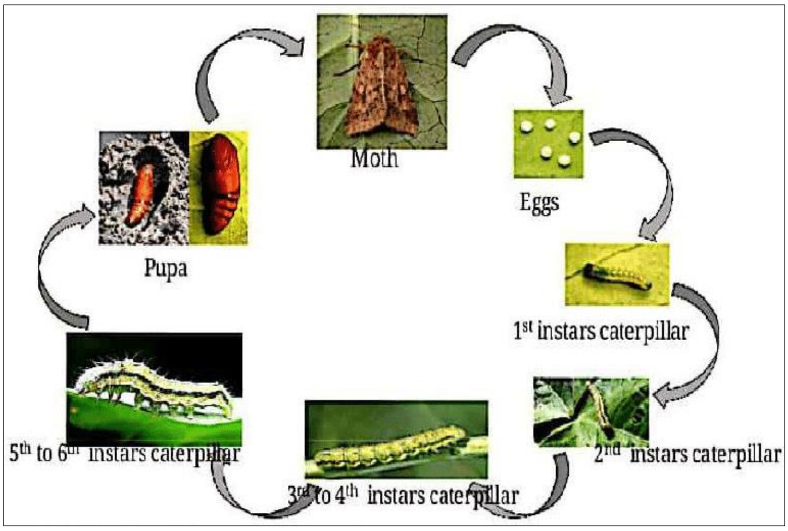


Figure 35 Life cycle of *Helicoverpa*; (Source: https://www.researchgate.net/figure/Life-cycle-of-Helicoverpa-armigera_fig1_349533603)

3.5. Orchid dupe

3.5.1. Lissopimpla excelsa (Costa, 1864)

*Lissopimpla i*s a stout, medium-sized wasp (25 mm) with an orange body, black wings and the abdomen has a checkered pattern of black and white spots on the upper surface. Although encountered in all summer crops, *Lissopimpla* appears to be less abundant than *Heteropelma*.

3.5.2. Lissopimpla also parasitises armyworm [26].

Figure 36 Female *Lissopimpla excelsa* (Costa, 1864) resting on a leaf. Note the dark coloured wings and long black ovipositor; (Source: Photo: P. Reid, CSIRO)

3.6. Orange caterpillar parasite

3.6.1. Netelia producta (Brullé, 1846)

Netelia is a slender, medium-sized (18 mm) orange wasp that is often seen in winter cereals at harvest it can be regularly found in summer crops, but one of the best places to see Netelia is at night around outdoor lights.

Netelia attacks both *Helicoverpa* and armyworm caterpillars [26],

Figure 37 Adult *Netelia* wasp parasitising a paralysed *Helicoverpa* larva; (Source: Photo: J. Hopkinson, DPI&F)

3.7. Study 4

Scientific Description: (Hymenoptera: Ichneumonidae)

Common name: slender wasp, parasitoid wasp

Importance: most are parasitoid of larvae of different species of insects butterflies, moths, flies, bed bugs, beetles and others. Some groups attack a variety of hosts and others they are extremely experts. Adults are free-living, feed mainly on nectar and pollen. These parasitoids can be found in different environments and are mainly more active. in partially open areas and with higher temperatures. Due to the parasitic characteristics, this family is considered of great importance in biological pest control programs (Figures 38A, 38B and 39) [27].

Figure 38 A *Mecynogea biggiba* Simon, 1903 parasitized by *Hymenoepimecis japi* Sobczak, Loffredo, Penteado-Dias & Gonzaga, 2009. A Adult female spider and first instar larvae B Adult female spider with second instar larvae on its abdomen C Third instar larvae of *H. japi* after killing its host spider D Third instar larvae consuming the hemolymph of *M. biggiba* E Detail of dorsal tubercles bearing several hooks *F* Cocoon of *H. japi* G Dense weave of cocoon threads in detail. Figure 38B Adults are free-living, feed mainly on nectar and pollen (Pollination); (Source: https://jhr.pensoft.net/article_preview.php?id=14817&skip_redirect=1)

Description: present complete metamorphosis, that is, from the eggs hatch larvae that pass from pupa to adult hood. The biology of Ichneumonidae is very diverse. Some groups are ectoparasites and other endoparasites, with solitary and other gregarious species. Adults vary in size, and they can reach up to 40 mm in length, with different shapes and colors and, in many species, the ovipositor is quite long and is used to place the eggs in the cavities where the hosts, being able to penetrate 13 mm or more. After locating the host, the female lays her eggs. on him or inside his body. The larva then feeds and develops on this host which is killed at the end of the larval cycle [27].

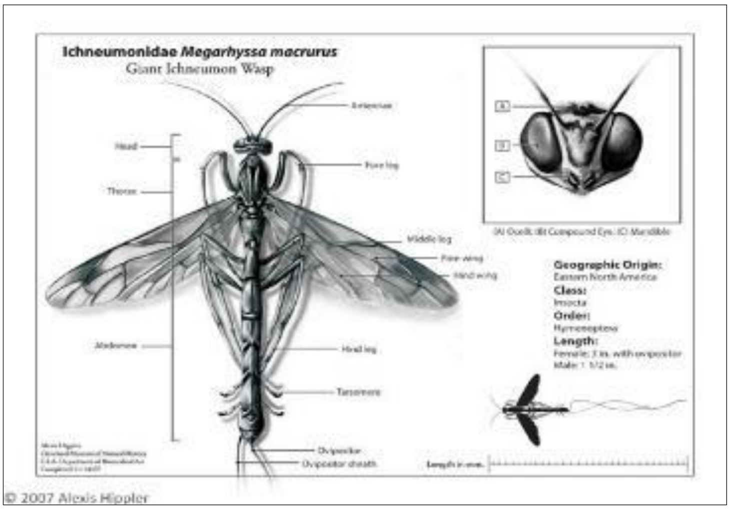


Figure 39 Entomology Illustration Plate: Giant Ichneumon Wasp on; (Source: https://www.behance.net/gallery/694201/Entomology-Illustration-Plate-Giant-Ichneumon-Wasp)

3.8. Study 5

3.8.1. Caterpillar parasitoids

Microcharops bimaculata (Ashmead, 1895) and *Microcharops anticarsiae* Gupta, 1987 (Hymenoptera: Ichneumonidae) *M. bimaculata* and *M. anticarsiae* have a wide geographic distribution. They occur in the United States, Central America and South America. The species *M. bimaculata* is a solitary endoparasitoid that parasitizes the early stages of caterpillars, causing mortality mainly in the third and fourth instars, and it can also cause the death of fifth instar caterpillars. This species is one of the most common parasitoids of the soybean caterpillar, *Anticarsia gemmatalis* Hübner, 1818 (Lepidoptera: Noctuidae), and its occurrence is associated with the presence of its host (Figures 40, 41, 42 and 44).

Figure 40 Adult of *Microcharops bimaculata* (Ashmead, 1895) (Hymenoptera: Ichneumonidae); (Source: https://www.researchgate.net/figure/Figura-14-Adulto-de-Microcharops-bimaculata_fig7_262602114)

Higher population density of *M. bimaculata* in soybean crops in the State of Paraná and soybeans in Santa Catarina and Rio Grande do Sul showed parasitism percentages between 60% and 70% in *A. gemmatalis* caterpillars. On a smaller scale, *M. bimaculata* is also cited as a parasitoid of the false groin caterpillar, *Chrysodeixis includens* (Walker, 1858) (Lepidoptera: Noctuidae), and the pod caterpillar, *Spodoptera cosmioides* (Walker, 1858) (Lepidoptera: Noctuidae).

Figure 41 *Microcharops anticarsiae* Gupta, 1987 (Hymenoptera: Ichneumonidae); (Source: https://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=391450)

Microcharops anticarsiae is another important parasitoid of caterpillars in the soybean crop. It has no preference for larval instar of the *A. gemmatalis* and parasite, equally, first to fourth caterpillars instars. *Microcharops anticarsiae* is very similar to *M. bimaculata*, but has the anterior thigh and tarsus posterior totally black, proposes a moderately depressed, distinct and apically open areola, which helps to differentiate between species.

Eggs are often found internally fixed in the cuticle of host insect larvae, mostly in the back of the abdomen, but they can be found circulation freely in the hemolymph. the period of incubation is 2.2 days with a minimum variation of 36 h to 72 h.

Figure 42 *Anticarsia gemmatalis* Hübner, 1818 (Lepidoptera: Noctuidae): adult and larvae; (Source: https://pt.wikipedia.org/wiki/Anticarsia_gemmatalis)

The larval stage lasts an average of 8.9 days and the pupal cocoon forms outside the body of the caterpillar measuring approximately 6 mm. Adults emerge after 8 days females present average longevity of 22 days, while

Males live approximately 19 days. The cycle lasts 41.6 and 45.9 days for females and males, respectively. The emergence of males is greater when parasitism occurs on first and second instar larvae [28,29,30,31,32,33].

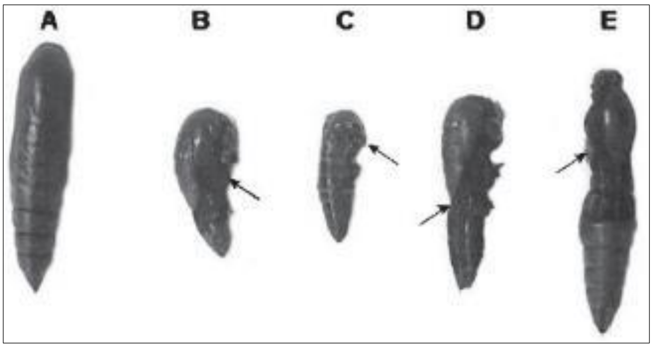


Figure 43 *Anticarsia gemmatalis* Hübner, 1818 (Lepidoptera: Noctuidae) pupae. A- normal. B to E- pupae with anomalies (arrows) that developed after the caterpillars were fed on soybean plants treated with nem oil; (Source: (Bioneem®) at Viçosa, Minas Gerais, Brazil)

4. Conclusion

The Ichneumonidae are ecto- or endoparasitoids of other arthropods, especially of the larvae and pupae of beetles (Coleoptera), wasps, bees and ants (Hymenoptera) and of moths and pollen (Lepidoptera). Because of this they are a very important group as biological control of pest. The human for each species is very specific in some cases and in others. There is a symbiotic relationship with a polydnavirus that infect its human being and prevents it from rejection the parasitoid.

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