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(REVIEW ARTICLE)

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Intraspecific ecological relationships harmonious and inharmonious of parasitoids Class Insect Order Hymenoptera and a review

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Abstract

The aim of this study was to perform a bibliographic summary on the harmonic and disharmonious intraspecific ecological relationships of parasitoids (Insect: Hymenoptera). The mini review consists of bibliographical research on the parasitoids of the Hymenoptera Parasitic group. The research was conducted in studies related to quantitative aspects of the Superfamily, Family, Genus and Species (taxonomic groups) and in conceptual aspects such as: parasitism, parasitoidism, mutualism, spider parasitoids, "cockroaches karate kick parasitoid wasps to avoid becoming zombies", kicking defense by the cockroach, Wasp 'walking' a roach and ant parasitoids. A literature search was carried out containing articles published from 1982 to 2021. The mini review was carried out in Goiânia, Goiás, from August to September 2021, through the Online Scientific Library (Scielo) and internet.

Keywords: Arthropoda; Insects; Spiders; Virus; Parasitism

1. Introduction

Ecological relationships are the interactions that take place between living beings, which can occur between individuals of the same species (intraspecific relationships) or individuals of different species (interspecific relationships). They can also be harmonic or disharmonious [1, 2].

Parasitism is a type of ecological relationship. Before highlighting their characteristics, we need to review the main aspects linked to ecological relationships, that is, interactions that occur between living beings, whether they are of the same species (intraspecific relationship) or of different species (interspecific relationship). These interactions can: benefit everyone involved, benefit only one of those involved, but without harming the other, harm one individual and benefit the other [1, 2, 3, 4]

When there is no harm to the interacting living beings, we have what we call a harmonic or positive relationship. The relationships that cause harm to one of the parties involved are called disharmonious or negative [1, 2, 3. 4].

Parasitoidism: In parasitism, an organism interacts with a host until it causes its death. After death, the parasitoid remains in the body of the organism for a period. Because it causes the death of the host in the interaction, this ecological relationship cannot be called parasitism [4].

Objective

The aim of this study was to perform a bibliographic summary on the harmonic and disharmonious intraspecific ecological relationships of parasitoids (Insect: Hymenoptera).

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2. Material and methods

The mini review consists of bibliographical research on the parasitoids of the Hymenoptera Parasitic group. The research was conducted in studies related to quantitative aspects of the Superfamily, Family, Genus and Species (taxonomic groups) and in conceptual aspects such as: parasitism, parasitoidism, mutualism, spider parasitoids, "cockroaches karate kick parasitoid wasps to avoid becoming zombies", kicking defense by the cockroach, Wasp 'walking' a roach and ant parasitoids. A literature search was carried out containing articles published from 1982 to 2021. The mini review was carried out in Goiânia, Goiás, from August to September 2021, through the Online Scientific Library (Scielo) and internet.

3. Studies carried out to prepare the bibliographic summary

3.1. Study 1

3.1.1. Siricidae Family (Insect: Hymenoptera)

The wood wasp is an insect native to Europe, Asia, and North Africa. It is considered a secondary pest in pine trunks in the places of origin, however when it was introduced in New Zealand, Tasmania and Australia it caused damage in large reforested areas, and especially in *Pinus* plantations, aged between 15 and 20 years, not thinned and overstocked (more than 1,600 to 1,700 plants/ha), a consequence of inadequate management or the lack of a market for wood at the beginning of the century (Figures 1, 2 and 3) [5, 6].

Figure 1 *Sirex noctilio* Fabricius, 1773 (Hymenoptera: Siricidae); Source: https://www.flickr.com/photos/63075200@N07/31605742467

Figure 2 Larva of *Sirex noctilio* Fabricius, 1773 (Hymenoptera: Siricidae) attacking wood; Source: evistacampoenegocios.com.br/vespa-da-madeira-alastra-sobre-florestas-de-pinus/larva-da-vespa-da-madeira-credito-susete-do-rocio-chiarello-penteado/

Pine species are planted in several countries and the planted area in Brazil currently occupies 1,562,782 hectares. The State of São Paulo has 144,802 ha of planted pine and together with the states in the southern region of the country, they have 94% of the Brazilian area. The main pest of this crop is the tree wasp *Sirex noctilio* Fabricius, 1773 (Hymenoptera: Siricidae) and is present in more than 1,000,000 ha in the country. The use of silvicultural methods and biological control help to control this pest in Brazil (Figures 3 and 4) [5, 6].

Figure 3 Wood damage caused by wasp larva; Source: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html

Figure 4 *Ibalia leucospoides* (Hockenwarth, 1785) (Hymenoptera, Ibaliidae) parasitoid of *Sirex noctilio* Fabricius, 1773 (Hymenoptera: Siricidae); Source: https://www.nzffa.org.nz/farm-forestry-model/the-essentials/forest-health-pests-and-diseases/Pests/Sirex-noctilio/Sirex-noctilioEnt20

Figure 5 *Megarhyssa macrurus* L. 1771. (Hymenoptera: Ichneumonidae) a parasitoid, ovipositing into its host through the wood of a tree. The body of a female is c. 2 inches (50 mm) long, with an ovipositor c. 4 inches (100 mm) long; Source: https://bugguide.net/node/view/1327750

Tremex columba (Linnaeus, 1763) (Hymenoptera: Siricidae), also known as the long-tailed giant ichneumonid wasp or long-tailed giant ichneumon wasp, is a species of large ichneumon wasp. It is a parasitoid, notable for its extremely long ovipositor that it uses to deposit an egg into a tunnel in dead wood bored by its host, the larva of a similarly large species of horntail (Figure 5) [7].

Megarhyssa macrurus is harmless to humans they are parasitoids on the larvae of the pigeon horntail *Tremex columba* (Linnaeus, 1763) (Hymenoptera: Siricidae) - Sawflies, which bore tunnels in decaying wood. Female *M. macrurus* can detect these larvae through the bark; they paralyze them and lay their eggs on the living but paralyzed larva; within a couple of weeks the *Megarhyssa* larvae will have consumed their host and pupate, emerging as an adult the following summer (Figure 6) [7].

Figure 6 *Tremex columba* (Linnaeus, 1763) (Hymenoptera: Siricidae); Source: https://biologicalsurvey.ca/ejournal/sgsbws_21/Siricidae/Species/Tremex/columba.html

3.2. Study 2

Parasitoid wasps are a large group of hymenopteran superfamilies, with all but the wood wasps (Orussoidea) being in the wasp-waisted Apocrita. As parasitoids, they lay their eggs on or in the bodies of other arthropods, eventually causing the death of these hosts. Different species specialize in hosts from different insect orders, most often Lepidoptera, though some select beetles, flies, or bugs; the spider wasps (Pompilidae) exclusively attack spiders (Figure 7) [8, 9 ,10].

Figure 7 Exemplary of the Orussoidea superfamily

Parasitoid wasp species differ in which host life-stage they attack eggs, larvae, pupae, or adults. They mainly follow one of two major strategies within parasitism: either they are endoparasites, developing inside the host, and koinobiont, allowing the host to continue to feed, develop, and moult; or they are ectoparasitic, developing outside the host, and idiobiont, paralyzing the host immediately. Some endoparasitic wasps of the superfamily Ichneumonoidea have a mutualistic relationship with polydnaviruses, the viruses suppressing the host's immune defenses [11, 12, 13].

3.3. Study 3

3.3.1. Aphelinidae family **(***Insect: Hymenoptera***)**

Parasitoids evolved only once in the Hymenoptera. Many parasitoid wasps are considered beneficial to humans because they naturally control agricultural pests. Some are applied commercially in biological pest control, starting in the 1920s with *Encarsia formosa* Gahan, 1924 (Hymenoptera: Aphelinidae) to control whitefly in greenhouses (Figures 8 and 9) [14, 15].

Figure 8 *Encarsia formosa* Gahan, 1924 (Hymenoptera: Aphelinidae); Source: https://www.insectimages.org/browse/detail.cfm?imgnum=2133029

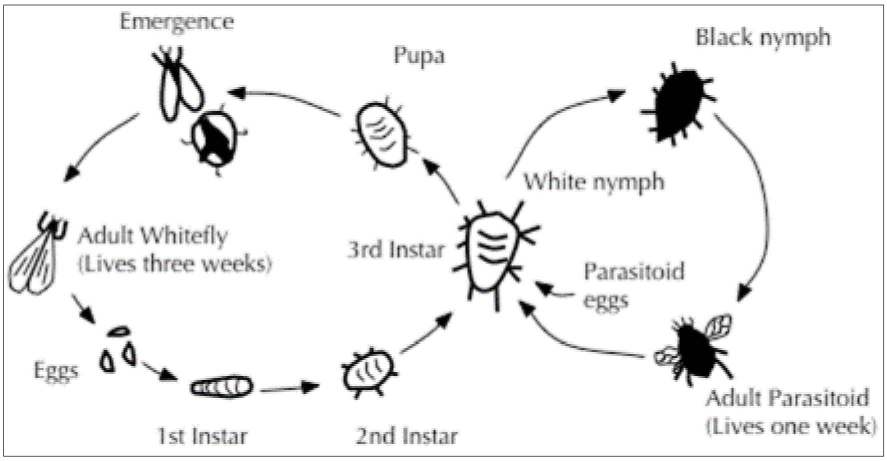

Figure 9 Life cycle of *Encarsia formosa* Gahan, 1924 (Hymenoptera: Aphelinidae); Source: https://en.wikipedia.org/wiki/Encarsia_formosa

3.4. Study 4

3.4.1. Family Pompilidae

Parasitoid wasps range from some of the smallest species of insects to wasps about an inch long. Most females have a long, sharp ovipositor at the tip of the abdomen, sometimes lacking venom glands, and almost never modified into a sting (Figure10) [16, 17, 18].

Many parasitoid wasps use larval Lepidoptera as hosts, but some groups parasitize different host life stages (egg, larva or nymph, pupa, adult) of nearly all other orders of insects, especially Coleoptera, Diptera, Hemiptera and other Hymenoptera. Some attack arthropods other than insects: for instance, the Pompilidae specialize in catching spiders: these are quick and dangerous prey, often as large as the wasp itself, but the spider wasp is quicker, swiftly stinging her prey to immobilize it [19, 20].

Adult female wasps of most species oviposit into their hosts' bodies or eggs. Some also inject a mix of secretory products that paralyze the host or protect the egg from the host's immune system; these include polydnaviruses, ovarian proteins, and venom. If a polydnavirus is included, it infects the nuclei of host hemocytes and other cells, causing symptoms that benefit the parasite (Figures 11, 12, 13, 14, 15 and 16) [19, 20].

Figure 10 The Pompilidae specialise in catching spiders Source: https://en.wikipedia.org/wiki/Spider_wasp#/media/File:IndianSpiderWasp.JPG; Source: htTtps://www.wikiwand.com/en/Parasitoid_wasp

Figures 11 and 12 Pompilidae larvae. Apparently healthy moth caterpillar feeds, grows, and molts but endoparasitic koinobiont wasp larvae eventually fill its body and; Source: https://www.wikiwand.com/en/Parasitoid_wasp

Figure 13 Potter wasp (Eumeninae), an idiobiont, building mud nest; she will then provision it with paralyzed insects, on which she lays her eggs; she then seals the nest and provides no further care for her young woman; Source: https://handwiki.org/wiki/Biology:Parasitoid_wasp

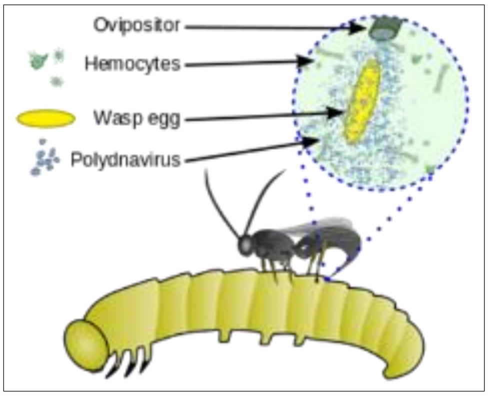

Figure 14 Polydnavirus-wasp mutualism: the virus protects koinobiont wasp eggs and larvae from immune suppression by the host's hemocytes; Source: https://www.wikiwand.com/en/Parasitoid_wasp

Figure 15 Parasitoid wasp (Ichneumonidae) pointing ovipositor at cinnabar moth larva, just after ovipositing. The larva wriggles vigorously to try to avoid the attack. The hosts of parasitoids have developed several levels of defense. Many hosts try to hide from the parasitoids in inaccessible habitats; Source: http://www.obsessedbynature.com/blog/2015/07/04/ichneumon-attacks-cinnabar-caterpillar-small-essex-skippers/

Figure 16 Spiders are air-breathing arthropods that have eight legs, chelicerae with fangs generally able to inject venom, and spinnerets that extrude silk; Source: https://www.google.com/search?q=Spiders+are+air-breathing+arthropods+that+have+eight+legs,&tbm=isch&hl=pt- Study 5

In South America, species may be referred to colloquially as *marabunta* or *marimbondo*, though these names can be generally applied to any very large stinging wasps. Furthermore, in some parts of Venezuela and Colombia, it is called *matacaballos*, or "horse killers", while in Brazil, some bigger and brighter species of the general *marimbondo* kind might be called fecha-goela/cerra-goela, or "throat locker [21]

Figure 17 Wasp dragging a spider to its nest; Source: https://pt.m.wikipedia.org/wiki/Ficheiro:Wasp_and_spider_02.jpg

In another study on *Pepsis thisbe* Lucas, 1895 (Hymenoptera: Pompilidae) chemosensory cues were shown to be used to detect specific hosts. Specific chemosensory cues attract the wasp to its prey, *Aphonopelma hentzi* (Girard, 1852) (Araneae, Theraphosidae), despite other host spiders of the same size and frequency being present. In studies on *Pepsis grossa* (Fabricius, 1793) (Hymenptera: Pompilidae) (formerly *P. formosa*), a pompilid of the southwestern United States, the wasps were found to have behavioral plasticity. Their hunting behavior concerning their host *Rhechostica echina* (Simon, 1892) (Araneidae: Theraphosidae). improved with experience. The time required to complete all behavioral components decreased with each spider killed (Figure 18) [21].

Figure 18 *Pepsis grossa* (Fabricius, 1793) (Hymenptera: Pompilidae); Source: https://www.bitsandbugs.com/pepsis-grossa/

Concerning mating behavior, males acquire perch territories to scan for incoming receptive females. In studies on the tarantula wasp *Hemipepsis ustulata* Dahlbom, 1844 (Hymenoptera: Pompilidae), larger males are more likely to acquire perch territories and territorial males appear to increase their chances of mating because receptive females fly to perch sites held by said males [21, 22].

Hemipepsis ustulata is a species of tarantula hawk wasp native to the Southwestern United States. Tarantula hawks are a large, conspicuous family of long-legged wasps which prey on tarantulas. They use their long legs to grapple with their prey before paralyzing them with a powerful sting. Their stings are ranked second-most painful in the insect world. They are solitary, displaying lekking territorial behavior in their mating rituals (Figure 19, 20, 21, 22, 23 and 24) [21, 22].

Figure 19 *Hemipepsis ustulata* Dahlbom, 1844 (Hymenoptera: Pompilidae); Source: https://www.flickr.com/photos/

Figure 20 *Dipogon subintermedius* (Magretti, 1886) (Hymenoptera: Pompilidae); Source: Image taken in Stuttgart, Germany

Figure 21 A Western Australian pompilid has captured a large huntsman spider; Source: https://en.wikipedia.org/wiki/Spider_wasp#/media/File:Spiderwasp1_feb09.jpg

Figure 22 Spider wasp flying with prey; Source: https://en.wikipedia.org/wiki/Spider_wasp#/media/File:Spider_wasp_flying.jpg

Figure 23 The anaesthetized spider is carried up to a nest in the roof; Source: https://en.wikipedia.org/wiki/Spider_wasp#/media/File:Spiderwasp2_feb09.jpg

Figure 24 Spider wasp with its prey near Heemstede, Netherlands; Source: https://en.wikipedia.org/wiki/Spider_wasp#/media/File:Spider_wasp_05.JPG

3.5. Study 6

3.5.1. Cockroaches' karate kick parasitoid wasps to avoid becoming zombies

The emerald jewel wasp (*Ampulex compressa Ampulex compressa* (Fabricius, 1781) (Hymenoptera: Ampulicidae)) is renowned for its ability to zombify the American cockroach (*Periplaneta americana* (Linnaeus, 1758) (Blattodea: Blattidae) with a sting to the brain. When the venom takes effect, the cockroach becomes passive and can be led by its antenna into a hole, where the wasp deposits an egg and then seals the exit with debris. In a new study, has found that for a cockroach not to become a zombie, the best strategy is be vigilant, protect your throat, and strike repeatedly at the head of the attacker (Figure 25).

Figure 25 Female of *Ampulex compressa* (Fabricius, 1781) (Hymenoptera: Ampulicidae) attacking immatures and adults of *Periplaneta americana* (Linnaeus, 1758) (Blattodea: Blattidae)

"The 'zombification' of the American cockroach by the emerald jewel wasp stands out as one of the most remarkable and well-studied examples of host behavioral manipulation by a parasitoid. "In order to reproduce, the emerald jewel wasp must somehow lead its much larger victim to a chamber, glue an egg to the cockroach in just the right spot, and seal the chamber with debris. "The host, which could dig its way out, must instead remain passively in the chamber while it is slowly eaten alive by the developing wasp larva (Figure 26) [22, 23].

Figure 26 A jewel wasp (*Ampulex compressa*) attacking an American cockroach (*Periplaneta Americana*). a Jewel wasps begin their attack by firmly grasping the plate-like pronotum of the cockroach with their mandibles. b After having paralyzed the front legs with a first sting into the first thoracic ganglion (not shown), the second sting is made into the head and brain of the cockroach; Source: Crédito da imagem: K.C. Catania, doi: 10.1159 / 000490341

In the study, the interactions between cockroaches and jewel wasps were investigated by high-speed video to determine the range of defensive behaviors used by cockroaches and to document the wasp's attack strategy. Many cockroaches detected the wasp as it approached, and they were able to mount a successful defense by stilt standing and kicking, or by removing the wasp with an escape response combined with a raking defense with the tibial spines of the limbs. "I saw that, before the wasp can get into position and deliver its sting, the cockroach uses a swift blow with a spiny back leg to deter its attacker (Figures 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 and 37) [24, 25].

Figure 27 The stilt-standing defensive posture of the cockroach. a Schematized dorsal view of a typical cockroach posture, with the wasp's target (the pronotum) indicated with a red arrow. b Schematized stilt-standing posture with the legs and one antenna oriented toward the approaching wasp. c The cockroaches commonly turned away from the wasp, allowing for a kicking defense with the powerful hind legs. d Side view of a cockroach in a typical posture. e Side view of stilt-standing in response to a wasp, illustrating the elevation of the cockroach's body. f Stilt-standing while orienting the legs and one antenna toward the cockroach. g Stilt-standing after turning to position the wasp behind, illustrating the cockroach's body angled away from the wasp. In this stance, the pronotum is distant and raised away from the wasp; Source: Crédito da imagem: K.C. Catania, doi: 10.1159 / 000490341

Figure 28 Kicking defense by the cockroach: (a) schematized sequence of movements (red arrows) during the kick; the hind leg is raised and extended rostrally, and then swept back through the target, often projecting the wasp many centimeters away; (b) frames captured from a video showing a defensive kick by a cockroach that impacts the wasp on the head and propels it away (top view); (c) frames captured from a video showing a kick with a similar result (side view); note the dorsal extension of the leg during the windup phase; (d) ventral view of a defensive kick, with the cockroach holding on to the top of the chamber; Source: Crédito da imagem: K.C. Catania, doi: 10.1159 / 000490341

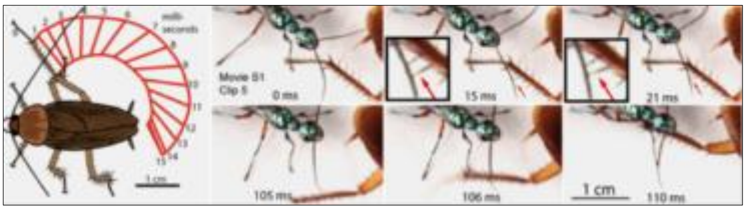

Figure 29 Timing and elicitation of a kick. a Schematic illustration of the hind leg's position every millisecond for the swing phase of a kick. The positions were taken from the trial shown in clip 4 of online supplementary Movie S1. Note that the movement of the cockroach's body is not illustrated; rather, the leg's positions are relative to the initial body position. b Close view of a kick as filmed with a camera attached to a microscope. Just prior to the kick, the wasp's

antenna deflects a single tibial spine (insets; red arrows). See clip 5 of online supplementary Movie S1 for the full trial; Source: Image credit: K.C. Catania, doi: 10,1159 / 000490341

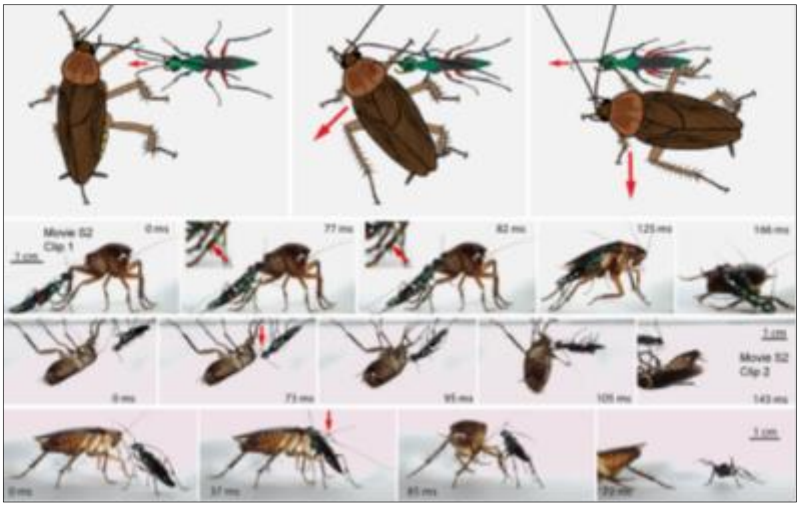

Figure 30 Escape responses elicited by a wasp's lunge. a–c Schematic illustration of a cockroach's escape, starting from a stilt-standing position (movements shown with red arrows). As the wasp lunges for the pronotum, contact is often made with one of the cockroach's legs or antennae, followed by a short latency turn by the cockroach. d Frames captured from a video showing a wasp's lunge for the pronotum of a stilt-standing cockroach, and simultaneously deflecting a tibial spine of one of the cockroach's legs (insets; red arrows). The subsequent escape response moves the pronotum with only milliseconds to spare. See online supplementary Movie S2, clip 1. e A wasp lunges for the pronotum of a still standing cockroach but hits the antenna with its mandibles (red arrow). Note that the roach and the wasp are holding on to the upper surface of the chamber. See online supplementary Movie S2, clip 2. f A wasp lunges for the pronotum of a stilt-standing cockroach but hits the antenna with its antenna (red arrow), followed by a short-latency turn by the cockroach; Source: Image credit: K.C. Catania, doi: 10,1159 / 000490341

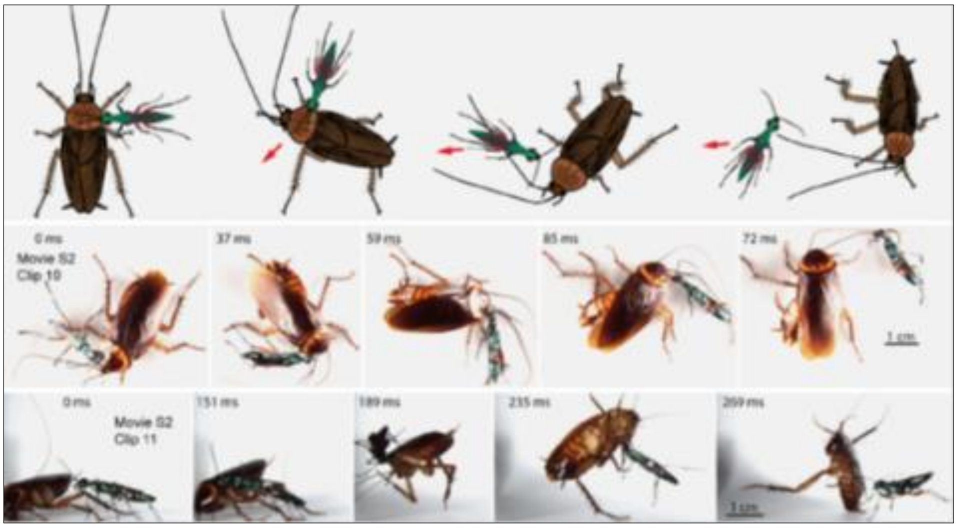

Figure 31 Escape responses elicited by a wasp's grasp to the pronotum. a Schematic illustration of successful escape after a pronotum grasp. If not already elicited, an escape response at this point was always triggered. The rapid turn sometimes dislodged the wasp (red arrows) but more often failed. b Frames captured from a video showing a wasp's dislodgment by a sudden turn. See online supplementary Movie S2, clip 10. c Frames captured from a video showing a wasp's dislodgment from turning. See online supplementary Movie S2, clip 11; Source: Image credit: K.C. Catania, doi: 10,1159 / 000490341

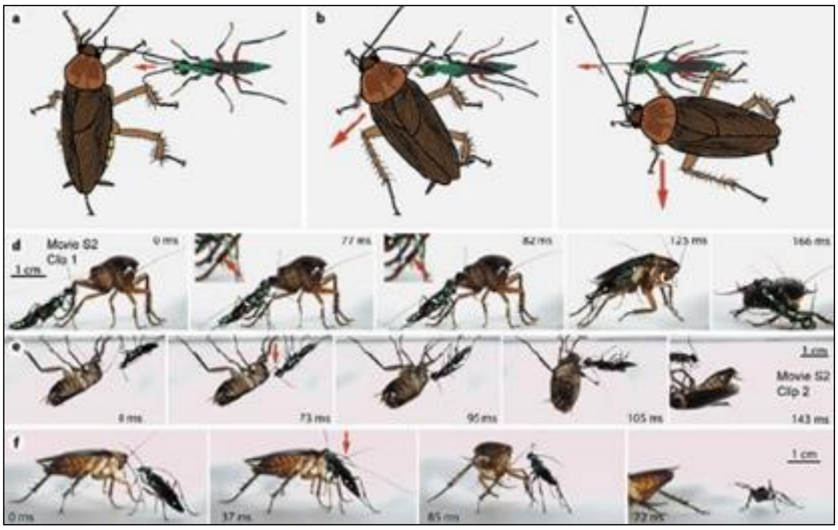

Figure 32 The subsequent escape response moves the pronotum with only milliseconds to spare. See online supplementary Movie S2, clip 1. e A wasp lunges for the pronotum of a stilt-standing cockroach but hits the antenna with its mandibles (red arrow). Note that the roach and the wasp are holding on to the upper surface of the chamber. See online supplementary Movie S2, clip 2. f A wasp lunges for the pronotum of a stilt-standing cockroach but hits the antenna with its antenna (red arrow), followed by a short-latency turn by the cockroach. Online supplementary Movie S2 clip 1 shows an example of a wasp contacting the leg during its attack; Source: Image credit: K.C. Catania, doi: 10,1159 / 000490341

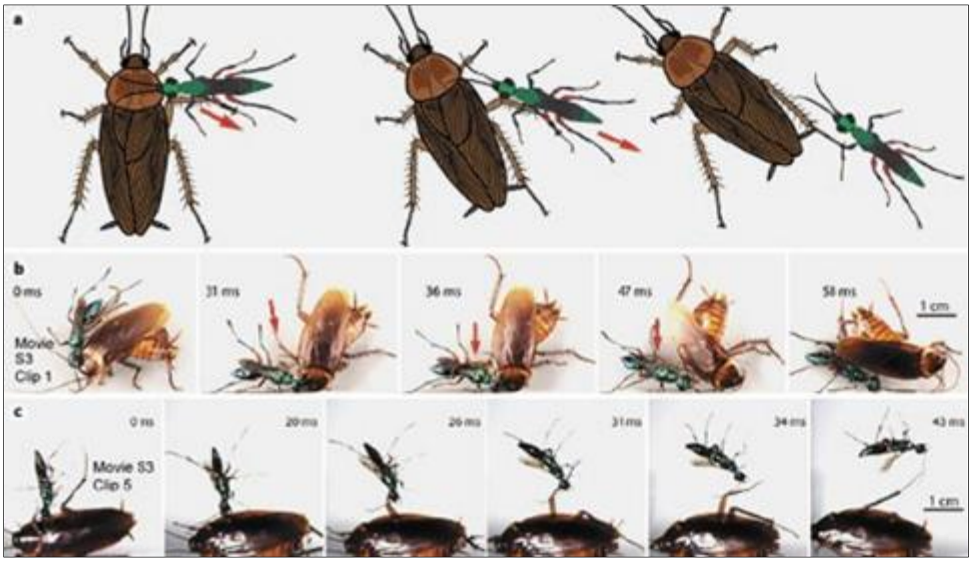

Figure 33 Use of tibial spines to dislodge a wasp. a Schematic illustration of a cockroach using the tibial spines on the midleg to dislodge a grasping wasp. The leg is drawn forward, pressed against the wasp, and then drawn backwards, while the body is simultaneously rotated away (red arrows). b Frames captured from a video showing the use of tibial spines (red arrows) to dislodge a wasp. See online supplementary Movie S3, clip 1. c Frames captured from a video showing the use of tibial spines to dislodge a wasp. See online supplementary Movie S3, clip 5; Source: Image credit: K.C. Catania, doi: 10,1159 / 000490341

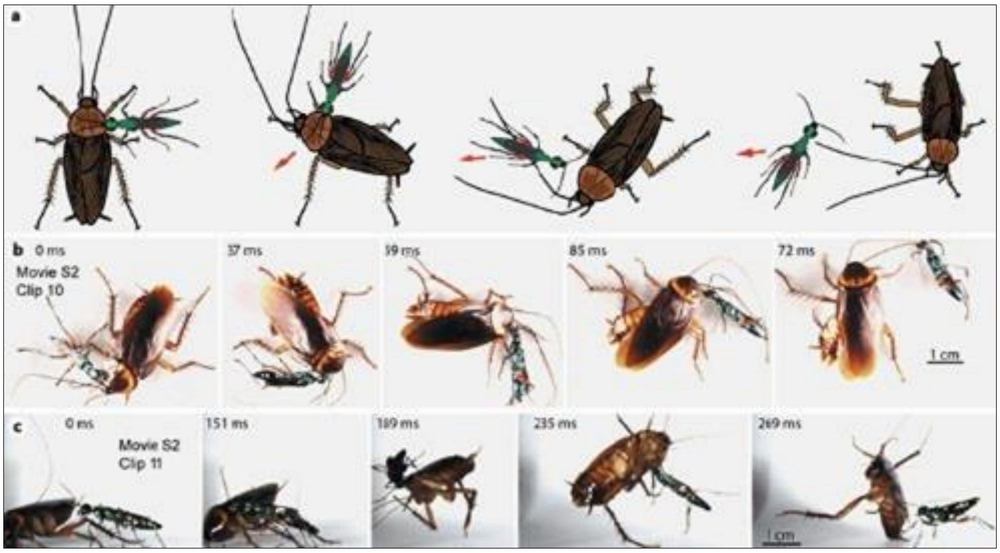

Figure 34 Once the wasp has secured a hold on its pronotum, the cockroach still has several defenses at its disposal. The most common behavior, observed in nearly every encounter that reached this stage, was the vigorous use of the spiny legs in a raking defense against the wasp. The utility of this defense was most obvious when the cockroach simply dislodged the wasp. a illustrates this behavior schematically, showing the use of the midleg. In general, the cockroach pushed the leg against the wasp, securely lodging the spines against the wasp's body and legs, and then simultaneously turned while moving its leg caudally. However, there were many variations, and the cockroaches used different legs, or combinations of legs, depending on the position of the wasp. b and c illustrate 2 examples. Online supplementary Movie

S3 (clips 1–10) shows these 2 trials in full form, in addition to 8 other trials during which the cockroaches successfully dislodged the wasps using this strategy; Source: Image credit: K.C. Catania, doi: 10,1159 / 000490341

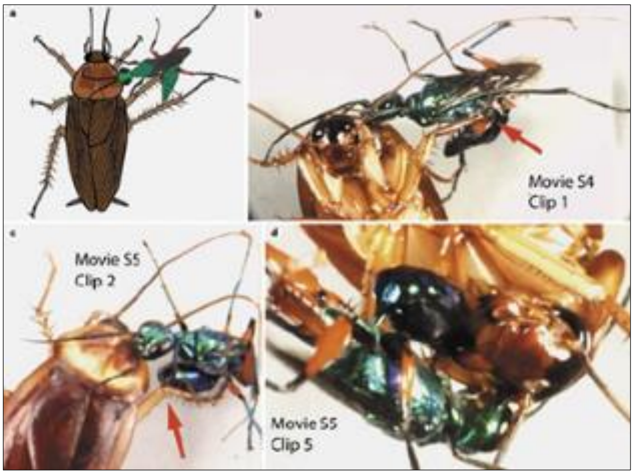

Figure 35 Stiff-arm defense and biting. a Schematic illustration. The cockroaches often brought one or more legs up against the wasp and lodged the spines against the abdominal joint or along the abdomen, making it difficult for the wasp to sting. b Frame captured from a video showing the position of the midleg (red arrow) holding back the wasp's abdomen. See online supplementary Movie S4 for this and additional examples. c The cockroaches often raked the tibial spines repeatedly against the wasp during the struggle (red arrow), and occasionally lodged the spines in between the abdominal segments. This provided purchase for pushing the abdomen and stinger away from the thorax. See online supplementary Movie S5 for this and additional examples. d Frame captured from a video showing a cockroach attempting to bite the wasp's abdomen during the sting. In this case, the cockroach had lodged its spines between the abdominal segments and thus used its foreleg to bring the abdomen briefly between its mandibles; however, it was apparently unable to damage the smooth, hard cuticle. See online supplementary Movie S5 for this and other examples; Source: Image credit: K.C. Catania, doi: 10,1159 / 000490341

Figure 36 Characteristic wasp posture during stinging. When delivering a sting, the wasps usually held their limbs up and away from the cockroach, in a pose reminiscent of a fencer. Presumably, the similarity is in both form and function, as the cockroach's powerful jaws might otherwise damage the wasp's delicate legs; Source: Crédito da imagem: K.C. Catania, doi: 10.1159 / 000490341

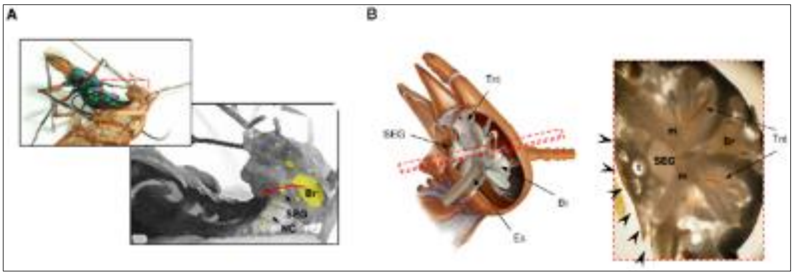

Figure 37 The jewel wasp stings a cockroach into the brain. (A) A photograph and a diagram showing the presumable trajectory of the wasp's stinger (red) inside the head of its cockroach host. The wasp holds the cockroach by the pronotum while bending the abdomen towards the cockroach's head, inserting the stinger through the soft neck cuticle.

The central nervous system of the cockroach is depicted in yellow. Br: Brain, SEG: subesophageal ganglion, NC: neck connectives. (B) Left: a lateral view of the cockroach head demonstrating the central nervous system (brain (Br) and SEG), the esophagus (Es) and the internal head skeleton (tentorium; Tnt). Right: light micrograph of a cross section of the head (taken from the plane shown as a dashed rectangle on the left), showing the brain, SEG, internal skeleton, trachea (t) and muscles (m). Different possible points of entry of the stinger through the soft neck cuticle are illustrated by arrowheads; Source: Crédito da imagem: K.C. Catania, doi: 10.1159 / 000490341

3.6. Study 7

3.6.1. Parasitized brood of Cyphomyrmex rimosus (Spinola, 1851) (Myrmicianae) ants

Figure 38 Parasitized brood of *Cyphomyrmex rimosus* (Spinola, 1851) (Myrmicianae) ants Parasitized brood of *Cyphomyrmex rimosus* (Spinola, 1851) (Myrmicianae) ants can be recognized by the gray or black color of the cuticle, rather than the cream white color of healthy brood. Scale bar=1.7 mm. b, c *C. rimosus* worker ants attacking adult *Acanthops* Serville, 1831 (Acanthopidae) wasps (b, female wasp; c, male wasp). Scale bars=1.3 mm [25]; Source: Catania KC. How not to be turned into a zombie*.* Brain*,* Behavior and Evolution*.* 2018; 92:32–46

Parasites often alter the behavior of their hosts in ways that are ultimately beneficial to the parasite or its offspring. Although the alteration of host behavior by parasites is a widespread phenomenon, the underlying neuronal mechanisms are only beginning to be understood. Focus on recent advances in the study of behavioral manipulation via modulation of the host central nervous system (Figure 39) [26].

Figure 39 Examples of fatal interactions between parasites and their insect hosts. (*a*) The *Camponotus* ant, mandibles locked onto a leafstalk, with *Hirsutella,* the anamorph of *Cordyceps unilateralis* (Fungi: Cordycipitaceae), emerging from the cuticle (*b*) The hairworm *Spinochordodes tellinii* (Camerano, 1888) (Gordiacea, Nematomorpha) emerging from a host cricket, *Nemobius sylvestris* (Bosc, 1792) (Orthoptera: Gryllidae), after inducing suicidal behavior in the host (*c*) The cockroach *Periplaneta americana* (Linnaeus, 1758) (Blattodea: Blattidae) stung in the brain by *Ampulex compressa* (Fabricius, 1781) (Hymenoptera: Ampulicidae); Source: (courtesy and copyright of R. Gal)

4. Conclusion

Due to the inadequacy of silvicultural practices, there is the existence of extensive reforested areas in precarious phytosanitary conditions, making the plantations more susceptible to attack by pests and diseases, exposing them to unpredictable losses. In this case, the occurrence of the wood wasp, *Sirex noctilio* Fabricius, 1773 (Hymenoptera: Siricidae) is included. Pompilidae is a family of Hymenoptera that hunt spiders. They are spider predators.

Compliance with ethical standards

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No conflict of interest.

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