A brief observation of morphological and behavioral similarities between the Ichneumonidae wasp *Cryptanura* sp. and its presumed mimic, *Holymenia clavigera* (Heteroptera: Coreidae), in Brazil

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Abstract

Some insects use wasps as a model to mimic and previous studies showed cases of Batesian mimicry involving this insect group. However, this relation is poorly known between phytophagous bugs, such as coreids, and Cryptinae ichneumonids. We found in a seasonal secondary forest in Brazil two similar insects representing different orders. The mimic seems to be *Holymenia clavigera* (Herbst) (Heteroptera: Coreidae) and its model, *Cryptanura* sp. (Hymenoptera: Ichneumonidae). This study therefore investigated similarities in morphological and behavioural aspects between *H. clavigera* and the wasp *Cryptanura* sp. *Holymenia clavigera* and its ichneumonid model are impressively similar in colour, size, foraging behaviour and sympatric range. The spanning movements of antennae by the coreid bug, which strongly resemble the foraging behaviour of the wasp, were observed frequently. The findings indicate strong evidences that *H. clavigera* is a mimic of the Ichneumonidae wasp, *Cryptanura* sp.

Keywords: mimetism, model, phytophagous, passion fruit, Cryptinae.

Uma breve observação de semelhanças morfológicas e comportamentais entre a vespa Ichneumonidae *Cryptanura* sp. e seu suposto mímico, *Holymenia clavigera* (Heteroptera: Coreidae), no Brasil

Resumo

Alguns insetos utilizam vespas como um modelo a imitar e estudos anteriores apresentaram casos de mimetismo Batesiano envolvendo este grupo de insetos. No entanto, esta relação é pouco conhecida entre percevejos fitófagos, tais como coreídeos, e ichneumonídeos Cryptinae. Encontramos em uma floresta secundária sazonal no Brasil dois insetos similares representando diferentes ordens. O mímico parece ser *Holymenia clavigera* (Herbst) (Heteroptera: Coreidae) e seu modelo, *Cryptanura* sp. (Hymenoptera: Ichneumonidae). Este estudo investigou semelhanças em aspectos morfológicos e comportamentais entre *H. clavigera* e a vespa *Cryptanura* sp. *Holymenia clavigera* e seu modelo ichneumonídeo são impressionantemente similares na cor, tamanho, comportamento de forrageamento e faixa simpátrica. Os movimentos abrangentes das antenas pelo percevejo coreídeo, que se assemelham fortemente ao comportamento de forrageamento da vespa, foram observados frequentemente. As descobertas apontam fortes evidências que *H. clavigera* é um mímico da vespa Ichneumonidae, *Cryptanura* sp.

Palavras-chave: mimetismo, modelo, fitófago, maracujá, Cryptinae.

1. Introduction

Mimicry occurs when a group of organisms, the mimics, have evolved to share common perceived characteristics with another group, the models, through the selective action of a signal-receiver or dupe (Franks and Noble, 2004). This phenomenon is one of the most celebrated examples of the power of natural selection (Evans, 1965) occurring in both plants and animals but it is most prevalent among insects (Franks and Noble 2002; Ito et al., 2004). The mechanism by which palatable species take advantage of their similarity in appearance to those that are unpalatable, in order to avoid predation, is called Batesian mimicry (Bates 1862; Franks and Noble, 2004).

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Hymenoptera have species with different ecological functions such as ecto, endo and hyperparasitoids, gall miners, herbivores, pollinators, predators and eusocial species (Reis et al., 2008; Santos et al., 2009; Pereira et al., 2009; Ramalho et al., 2009) with well developed defense mechanisms against predators (Taniguchi et al., 2005). So, it is possible that a large number of their representatives must be involved, actively or not, in mimicry (Lorenzi et al., 2004).

Ichneumonidae wasps are one of the largest families of the Insecta class represented by 35 subfamilies and approximately 60.000 species (Wahl, 1993; Yu and Horstmann, 1997). A broad range of insects use these wasps as models to mimicry, perhaps due to the conspicuous habits of their representatives (Rettenmeyer, 1970) and because these parasite wasps have acquired an important evolutionary tool against natural enemies: the sting. So, the mimics that are not able to sting, or that have no efficient defensive apparatus, may resemble wasps to help deter predation. Once predators have learned to avoid the "true wasps", they similarly avoid the mimics (Golding et al., 2005). In general the mechanisms involving the mimicry phenomenon in insects are not restricted to visual signals (e.g., colour) and more than one type of signal may be employed such as morphological, chemical and behavioural ones (Flach et al., 2006).

This study reported morphological and behavioural aspects of the phytophagous bug *Holymenia clavigera* (Herbst) (Heteroptera: Coreidae), a pest of passion vine species (Passifloraceae) in Brazil, which strongly resembles the poorly-known ichneumonid wasp *Cryptanura* sp. (Hymenoptera: Ichneumonidae).

2. Material and Methods

1.1. Area

The study was conducted in a 20 ha fragment of native forest (semideciduous seasonal forest) of the Department of Animal Biology of the Federal University of Viçosa (UFV) in Viçosa, Minas Gerais State, Brazil at 20°45' S, 42°51' W and an altitude of 651 m. This area has native and exotic species, including *Psidium guajava*, *Psidium cattleianum* and *Eucalyptus* spp. (Myrtaceae) and other arboreal and herbaceous plants with a floristic pattern similar to that described by Marangon et al. (2003). Mean annual temperature was 14.6 °C to 21.8 °C and annual rainfall of 1,220 mm.

1.2. Sampling Cryptanura sp. and H. clavigera adults

Samplings were conducted from January 2007 to June 2007 including the rainy and hot seasons which are expected to be the main fly season for most Hymenoptera species from Viçosa. The sweeping vegetation was used to sample the specimens through an entomological vacuum glass (150 mL). However, due to the intense foraging habit of ichneumonid wasps near the leaf litter, and the high labour effort required by sweeping, yellow tray traps were additionally used.

Samples were taken along two transects, each one 200 m long by 20 m wide with an area of 8000 m^2 (Zanuncio et al., 2004; Reis et al., 2008). The collector initially crossed the transect to recognise the path. After this, each transect was walked slowly from 09:00 to 12:00 considering especially the area and its sides. A total of 12 samples were taken monthly on random days. Collecting time was chosen due to the peak of ichneumonid wasps foraging (AIA Pereira, personal observations). Only *H. clavigera* and *Cryptanura* sp. adults were collected, including those remaining on leaves, branches or any other substrate. We did not keep rigorous tracks on the host species of the ichneumonid wasp. The yellow tray traps were a plastic rectangular 31 cm long, 25 cm wide and 6 cm high. Fifteen yellow tray traps were installed on the ground spacing 10 m between them.

All insects collected were stored in ethanol 70% and voucher specimens were deposited at the entomological collections of the Regional Museum of Entomology of the UFV and at the Federal University of São Carlos and at the Federal University of São Carlos, São Paulo state.

1.3. Morphometrics

Thirty morphological characters of *H. clavigera* and *Cryptanura* sp. were compared because they were easily recognised. Specimens of both species were measured with an ocular micrometer (Wild Heerbrugg 20x) in a Leica MZ-8 stereomicroscope and millimetres were used as the standard unit. The character terminology used was that of Zúñiga-Ramírez (2004).

1.4. Behavioural Notes

Behavioural notes of *Cryptanura* sp. were taken a few seconds before its capture by sweeping vegetation. Observations on the behaviour of *H. clavigera* were made in the same way in the area studied and additionally in a three year-old yellow passion fruit orchard at the Fruit Department (UFV) spaced 2.5 x 5.0 m.

Photographs of *H. clavigera* and *Cryptanura* sp. adults were taken in the field with the macro mode of a Sony DSC-W70 Cyber-shot (7.2 megapixels) digital camera and detailed photographs were taken using the magnification of up to 20x with a stereomicroscope manually coupled with the lens of a camera directly to the ocular of the microscope.

3. Results

A total of 22 specimens were collected with *Cryptanura* sp. (n = 18) being more abundant than *H. clavigera* (n = 4). Samplings through sweeping vegetation collected more insects (n = 16) than yellow tray traps (n = 6) (Figure 1 A and B). Both methods were used to collect the ichneumonid wasp but yellow tray traps did not attract the bugs (Figure 1A). The number of *Holymenia clavigera* and its model are similar in size and shape with fourteen morphometric characters being similar between them (Table 1). Only the lengths of the first antennomere (F = 271.06; p = 0.003), compound eyes

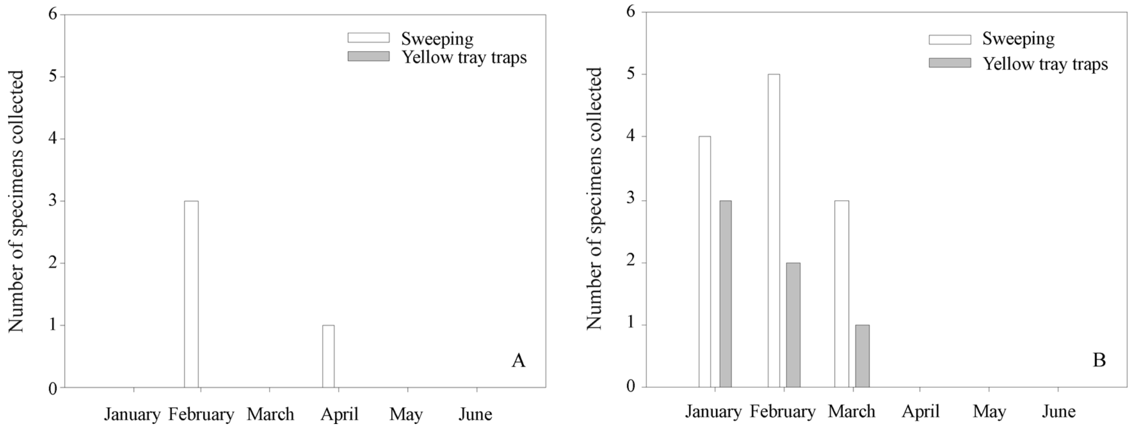

Figure 1 - Number of specimens of *Holymenia clavigera* (Heteroptera: Coreidae) (A) and *Cryptanura* sp. (Hymenoptera: Ichneumonidae) (B) collected by sweeping vegetation and yellow tray traps in a secondary forest area in Viçosa, Minas Gerais state, Brazil (2007).

($F = 50.00$; $p = 0.01$) and hindtarsus ($F = 20.83$; $p = 0.04$) were longer in *Cryptanura* sp. than in *H. clavigera* (Table 1). *Holymenia clavigera* has a wasp-shape (Figure 2A) with a slightly longer body than *Cryptanura* sp. (Table 1). The antennae of both species are long measuring 80 and 86.73% of the body for *H. clavigera* and *Cryptanura* sp., respectively (Figure 2 A and B). Hindfemur and hindtarsus are longer for both species.

Both species have similar body colour (Figure 2 C and D). The head (Figure 2 E and F) and thorax (Figure 2 G and H) have a set of white spots which contrast with their dark eyes, head and the hind and dorso-lateral sides of their thorax. The abdomen of both species is entirely red (Figure 2 I and J). The ovipositor sheath of *Cryptanura* sp. females is salient with 3.2 ± 0.8 mm long but no body structures or appendices on the bug resembled the ovipositor of the wasp. Their fore and hind wings are hyaline with salient nervures.

The colour pattern of the antennomers, fore, mid and hind legs was also similar between *H. clavigera* and *Cryptanura* sp. with two dominant colours on the antenna (black and white) and two on the legs (yellow and red) for both insects (Figure 3). Their antennae are dark with a whitish band towards its apex (the white band comprises segment 5 in the bug, and 2 in the ichneumonid wasp).

At our field site, foragers of both species moved solitarily about the forest floor, searching in and above leaf litter. The foraging period for *H. clavigera* and *Cryptanura* sp. were synchronised with the latter showing intense foraging behaviour . This wasp remained resting on the substrate (fresh or dry leaves and branches), on average, 7.00 ± 2.30 seconds ($n = 6$), while *H. clavigera* spent more time on their substrate (28.20 ± 3.10 seconds) ($n = 10$) that was composed exclusively of fresh leaves. However, when disturbed, the bug spent less than 3 seconds until rapidly flying away. In resting moments, an active vibration behaviour by the antennae was observed for *H. clavigera* such as its model did. When the bug was in flight, the white stripe along the sutural margin causes the forewing to appear very narrow, resembling the thicker fore-costal margin of the wasp.

4. Discussion

The sampling scheme made it possible to observe a frequency-dependent relationship because the abundance of the model *Cryptanura* sp. was almost fourfold that of the mimic, *H. clavigera*. Theory predicts that the benefit of mimicry depends on the abundance of the model and it is more effective when the ranges of the mimic overlap that of the model (Pilecki and O'Donald, 1971; Merrill and Elgar, 2000; Pfennig et al., 2001). This frequency-dependent relationship is an important prerequisite for Batesian mimicry by increasing the opportunity of learning by predators. However, some mimics such as ants not always follow this pattern because they may nest independently of the model and these social insects can develop defense mechanisms against predators (Ito et al., 2004). Heteroptera insects may bite their antagonist but this is not true for phytophagous coreids such as *H. clavigera* who have no defensive apparatus and when disturbed, only flew away.

Some premises upon which Batesian mimicry is based (Huheey, 1964; Rettenmeyer, 1970) were attained in the present study such as the mimic should be less abundant than the model, the mimic should be found at the same place and time as the model and the model and mimic should be conspicuous or readily seen by potential predators. Although other premises were not proven experimentally, they can be assumed as being the non-palatability to predators by the model, the palatability by the mimic and the learning or associate non-palatability with the colour pattern of the model by predators. Some Hymenoptera (e.g. ants) are considered to be unfavourable as prey for vertebrate predators because of their mass aggression, defensive chemicals, strong mandibles and painful stings (Redford, 1987) as tested for *Lasius spathepus* Wheeler (Hymenoptera: Formicidae) against

Table 1 - Morphometric parameters (mm) (± SE) of *Holymenia clavigera* (Heteroptera: Coreidae) and *Cryptanura sp.* (Hymenoptera: Ichneumonidae) collected by sweeping vegetation in a fragment of native forestry at the Federal University of Viçosa in Viçosa, Minas Gerais state, Brazil.

Parameters	***Holhymenia clavigera* (n = 4)**	***Cryptanura* sp. (n = 12)**	**Contrast (F ratio)**
Total antenna length[a]	16.00 ± 0.40	12.75 ± 0.45	29.13*
A1[b]	0.85 ± 0.15	5.65 ± 0.25	271.06*
A2 [b]	3.05 ± 0.05	2.15 ± 0.05	162.00*
A3 [b]	3.85 ± 0.15	4.95 ± 0.25	14.23
A4 [b]	3.25 ± 0.05	_	_
A5 [b]	5.00 ± 0.40	_	_
Head width	2.50 ± 0.00	2.95 ± 0.15	6.40
Head length	2.75 ± 0.05	1.40 ± 0.10	145.80*
Vertex width[c]	1.20 ± 0.00	1.35 ± 0.05	2.00
Eye length	0.75 ± 0.05	1.25 ± 0.05	50.00*
Eye width	0.80 ± 0.00	0.80 ± 0.10	0.20
Ocelli length	0.20 ± 0.00	0.20 ± 0.00	0.20
Ocelli width	0.20 ± 0.00	0.20 ± 0.00	0.00
Thorax lenght	5.25 ± 0.15	5.75 ± 0.25	2.94
Thorax width	4.00 ± 0.00	2.35 ± 0.50	18.30*
Forefemur length	5.75 ± 0.25	3.55 ± 0.35	26.16*
Foretibia length	6.60 ± 0.20	4.25 ± 0.15	60.50*
Foretarsi length[d]	10.20 ± 0.20	6.25 ± 0.25	0.016
Midfemur length	3.10 ± 0.10	2.00 ± 0.10	88.36*
Midtibia length	4.25 ± 0.45	3.55 ± 0.55	0.97
Midtarsi length[d]	7.75 ± 0.25	5.40 ± 0.60	6.23
Hindfemur length	2.95 ± 0.25	2.85 ± 0.75	152.20*
Hindtibia length	3.00 ± 0.10	2.55 ± 0.15	13.07
Hindtarsi length[d]	3.15 ± 0.15	5.10 ± 0.40	20.83*
Forewing length	14.05 ± 0.85	12.25 ± 0.75	2.52
Hindwing length	10.15 ± 0.15	7.85 ± 0.35	36.48*
Forewing width	3.55 ± 0.35	3.65 ± 0.25	0.054
Hindwing width	2.70 ± 0.30	1.55 ± 0.55	3.36
Abdomen width	3.80 ± 0.20	2.15 ± 0.05	64.05*
Body length[e]	20.00 ± 0.20	14.70 ± 0.40	140.45*

[a]Sum of each antenommere length; [b]the letter "A" followed by arabic algarisms represents the length from the first (on the tip of the antenna) to the sixth (on the basis of the antenna) antenommere; [c]distance between eyes; [d]sum of tarsomeres; etotal sum of the head (without antenna), thorax and abdomen length; * Significantly at $p < 0.05$ by the F test.

Japanese treefrogs (Taniguchi et al., 2005). Painful stings are absent in ichneumonid wasps, but they can use their long ovipositor as a defensive apparatus, biting their enemies continuously. This last should also be the main defensive apparatus for the ichneumonid wasp.

The mimicry between *H. clavigera* and *Cryptanura* sp. might have evolved in relation to avian predation because any other natural enemy was observed using, as food source, adult bugs. For this reason, the colour pattern of the body of the ichneumonid wasp including appendages such as legs and antennae was copied by the mimic bug. This suggests the importance of visual cues, which are important tools for hunting prey by visually-oriented predators (Goldsmith, 1990), to avoid predation.

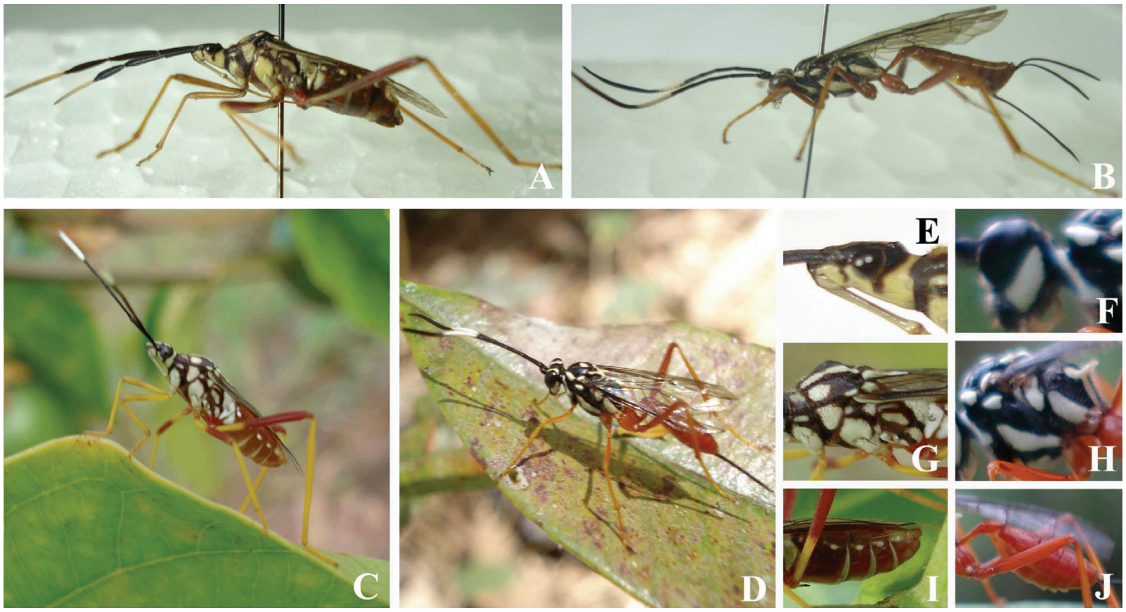

Figure 2 - The mimic *Holymenia clavigera* (Heteroptera: Coreidae) and its model, *Cryptanura* sp. (Hymenoptera: Ichneumonidae). Lateral view of *H. clavigera* (A) and *Cryptanura* sp. (B) adults mounted. Adult females of *H. clavigera* (C) and *Cryptanura* sp. (D) on field. Lateral view of the head of *H. clavigera* (E) and *Cryptanura* sp. (F). Lateral view of the thorax of *H. clavigera* (G) and *Cryptanura* sp. (H) and lateral view of the abdomen of *H. clavigera* (I) and *Cryptanura* sp. (J).

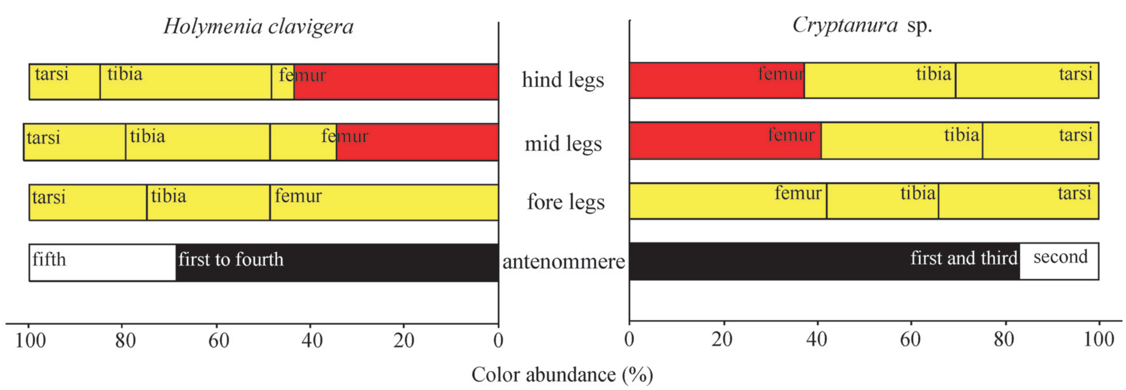

Figure 3 - Colour pattern of body parts of *Holymenia clavigera* (Heteroptera: Coreidae) and *Cryptanura* sp. (Hymenoptera: Ichneumonidae). Colour abundance was obtained through measuring (in mm) the lengths of each antenommere, hind, mid and fore legs and quantifying the abundance of colours (in mm) for each item than this data were transformed in percentage.

Even so, this remains to be studied in future. Insectivorous avian predators have an important role in the balance of food webs in several environmental systems (Merrill and Elgar, 2000) and other studies involving hymenopterans as models also relate cases of mimicry to avoid vertebrate predators (Harris, 1978; Merrill and Elgar, 2000).

The visual resemblances between *H. clavigera* and *Cryptanura* sp. also extended to behaviour despite their very different ecology. The antennal tips of *Cryptanura* sp. were used very rapidly to touch the host substrate, with the antennae sweeping repeatedly from laterally to medially as also reported for *Echthrus reluctator* (Linnaeus) (Hymenoptera: Ichneumonidae) (Laurenne et al., 2009) when foraging concealed hosts. These movements were showed also for *H. clavigera*, suggesting that specific foraging signals from the ichneumonid wasp were identically assumed by the bug. Movements by antennae of Heteroptera may be associated to important ecological cues as for predation (Lemos et al., 2005), alert (Sant'Ana et al., 1997; Thomas and Manica, 2005) or courtship process where the females can reject (or not) sexual partners according to the signals used (Awan, 1988; Capone et al., 1995; Wang and Millar, 2000; Moraes et al., 2005). However, the antennal behaviour of *H. clavigera* did not seem to be linked with any of the described cases what indicates that this bug must spend energy moving its antennae exclusively to mimic the foraging behaviour of the ichneumonid wasp. This is in line with several works which emphasise that some Batesian mimics of Hymenoptera should exhibit close behavioural convergence with their models. The mimetic hoverflies, *Sphecomyia vittata* (Wiedemann), *Ceriana signifera* (Loew), *Tenthredomyia abbreviate* (Loew) and *Spilomyia hamifera* Loew hold their antennae in positions which suggest the geniculate antennae of wasps (Waldbauer, 1970) and the dronefly *Eristalis tenax* (Linnaeus) (Diptera: Syrphidae) was able to mimic the flight behaviour of honeybees (Golding et al., 2001).

The mimicry reported was based on morphological and behavioural similarities between *H. clavigera* and *Cryptanura* sp. despite its sympatric occurrence. The degree of palatability of these insects to potential predators remains to be confirmed. However, the field-observed signals strongly suggest that the similarities between these species represent a mimicry relationship.

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