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Biology of Sarcophagidae (Diptera): Mini review

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Abstract

The aim of this study is to report the Biology of Sarcophagidae. The mini review consists of bibliographical research on the muscoid dipterans (Muscomorpha) (Order: Diptera). The research was carried out in studies related to quantitative aspects of the Family and Species (taxonomic groups) and in conceptual aspects such as: geographic distribution, biology, traps, life cycle, vector of bacteria and importance in Forensic Entomology. A literature search was carried out containing articles published from 1971 to 2021. The mini review was prepared in Goiânia, Goiás, from August to September 2021, through the Online Scientific Library (Scielo), internet, ResearchGate, Academia.edu, Frontiers, Publons, Qeios and Portal of Scientific Journals in Health Sciences, https://goo.gl/gLTTTs and https://www.growkudos.com/register.

Keywords: Muscomorpha; Scielo; Forensic Entomology; Enterobacteria; Brazil

1. Introduction

Some species of flies included in the Suborder Muscomorpha (Cyclorrapha) are of fundamental medical and veterinary importance, since they can produce myiasis and act in the transmission of pathogens to humans and animals. They have been found to carry over 100 species of disease-causing organisms such as bacteria, protozoa, and helminths. In addition to saprophagy/necrophagy, the main habits include some parasitoids, obligatory or facultative, and others that cause myiasis (Figure 1) [1, 2, 3, 4, 5,].

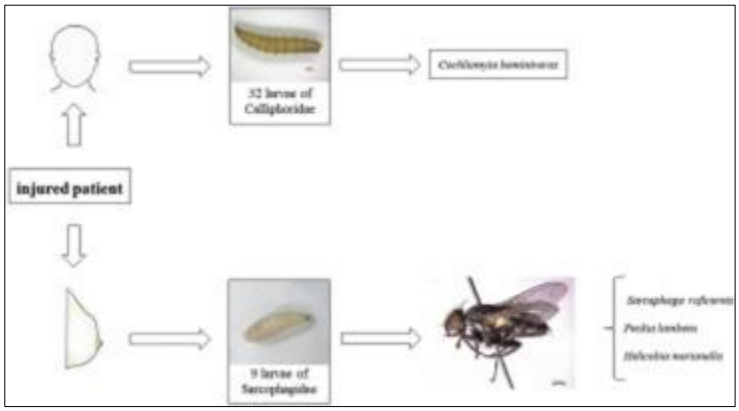

Figure 1 Myiasis in humans: Case reports in Northeastern Brazil including multispecies co-infestation by Sarcophagidae; (Source: https://www.sciencedirect.com/science/article/abs/pii/S1383576921001549)

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Sarcophagidae is one of the two families with the highest species richness among the calypterated Diptera of the superfamily Ostroidea, but it has been little studied worldwide, especially in the Neotropical Region. Sarcophagidae are viviparous insects or, rarely, ovoviviparous. On the other hand, this dipterous takes relevant importance in public health, for being the vehicle of a pathogenic microorganism to human beings (Figure 2) [5, 6,7,8,9,10].

Figure 2 Sarcophagidae specimen; (Source: https://www.istockphoto.com/br/foto/carne-voar-sarcophagidae-isolada-no-branco-gm962837178-262980729)

The monophilia of the family is a consensus among authors, both based on morphological and molecular characters, as well as on the three subfamilies recognized in it: Miltogramminae, Paramacronychiinae (Figures 3 and 4) and Sarcophaginae. The general morphology of sarcophagids is quite uniform (chest with three longitudinal black stripes and checkered abdomen) and the species distinction is mainly based on male genital characters. Females lay larvae and the habits of their immatures are quite varied, with the majority being saprophagous/scavengers, which includes them among the main decomposers of animal organic matter and gives them forensic importance [6,7,8,9,10,16,17,18].

Figure 3 Specimen of Miltogramminae; (Source: https://bugguide.net/node/view/1540804)

The subfamily Miltogramminae, with little neotropical diversity, presents dipterans with sizes ranging from small to medium, with species having kleptoparasitic larvae of Hymenoptera. The subfamily Paramacronychiinae, absent in the neotropical region, presents dipteran parasitoid or insect predators, land snails and turtle eggs, in addition to being considered producers of myiasis in mammals [11,12,13,14,15,16,17,18].

Figure 4 Specimen of Paramacronychiinae; (Source: https://photodune.net/item/fly-with-red-eyes-on-a-white-background/21528271)

The subfamily Sarcophaginae (Figure 5 and 6) has the greatest diversity of species and distribution concentrated in the New World. Most species are medium in size, although there are large (20 mm) and small (5 mm) species. Its larvae have different habits, with species that are saprophagous, scavengers, coprophagous, producing myiasis in vertebrates, insect parasitoids, predators of spiders, terrestrial snails and myriapods [11,12,13,14,15,16,17,18].

Figure 5 Sarcophaginae specimen; (Source: https://elp.tamu.edu/ipm/bugs/family-sarcophagidae-flesh-flies/diptera-sarcophagidae-subfamily-sarcophaginae-flesh-flies-a/)

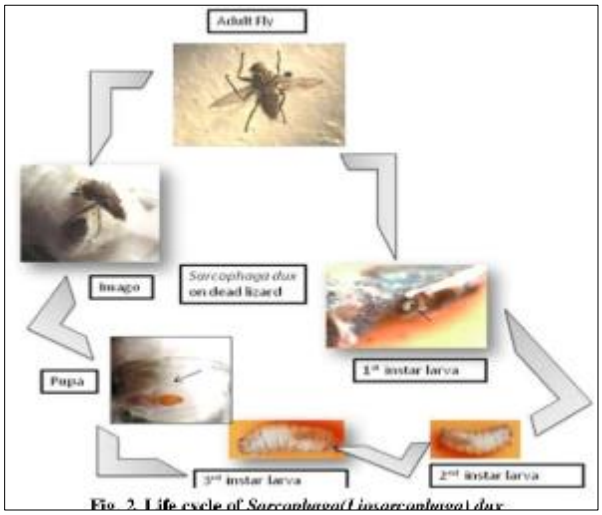

Figure 6 Life cycle of a Sarcophagidae; (Source: https://www.semanticscholar.org/paper/The-first-report-of-the-life-cycle-of-Sarcophaga-(-Chakraborty))

Objective

The aim of this study is to report the Biology of Sarcophagidae.

2. Methods

The aim of this study is to report the Biology of Sarcophafidae. The aim of this study is to report the Biology of Sarcophafidae. The bibliographical research on the *muscoid dipterans* (Muscomorpha) (Order: Diptera). The research was carried out in studies related to quantitative aspects of the Family and Species (taxonomic groups) and in conceptual aspects such as: geographic distribution, biology, life cycle, traps vector of enterobacteria and importance in Forensic Entomology. A literature search was carried out containing articles published from 1971 to 2021. The mini review was prepared in Goiânia, Goiás, from August to September 2021, through the Online Scientific Library (Scielo), internet, ResearchGate, Academia.edu, Frontiers, Publons, Qeios and Portal of Scientific Journals in Health Sciences, https://goo.gl/gLTTTs and https://www.growkudos.com/register.

2.1. Methods used to survey insects including the species, subfamilies, families of Sarcophagidae

2.1.1. Metal Container traps

Regarding the collection of parasitoids in animal feces (chicken, cattle and buffalo feces) we used the following methodology. Feces were removed from the farm sheds placed in 10 basins to be transported to the laboratory for removal of pupae. In the laboratory, pupae were obtained by flotation. The pupae were removed and placed on absorbent paper for drying and later individualized in glass capsules for the emergence of adult flies or parasitoids (Figure 7).

Figure 7 Metal Container traps

Method with animal carcasses in rural areas using two pig carcasses weighing approximately 10 kg each were used as bait. The pigs were mechanically killed with a blow to the head and immediately placed in metal frame cages to exclude large vertebrate scavengers. Under the cages, metal trays with sawdust were placed to collect pupae. The pupae were extracted by flotation in water. The pupae were placed individually in gelatin capsules for the emergence of adult flies or parasitoids.

Among vertebrates, the use of pig carcasses (*Sus scrofa* Linnaeus) (Figure 8) has been the most accepted model in experiments in Forensic Entomology for comparison with humans. This choice is due to the similarities of domestic pigs to humans, about tegument with few hairs, size of the chest cavity and internal characteristics.

Figure 8 pig carcasses (*Sus scrofa* Linnaeus); (Source: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Frepositorio.ufrn.br%)

2.1.2. Method for collecting feces

Fresh animal feces collected from pastures, pens or poultry farms are placed in 10 round plastic supports 20 cm in diameter. The feces remained exposed for 15 days in the environments mentioned above. After this period, the feces

are sent to the laboratory to extract the pupae using the flotation method. The pupae are removed with the aid of a sieve, placed on absorbent papers to dry, and later, individually stored in gelatin capsule until the emergence of flies and/or parasitoids. The parasitoids and flies that have emerged are identified and stored in 70% alcohol (Figure 9).

Figure 9 Bovine feces present in black plastic containers; (Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2168137/)

2.2. Study 1

The aim of this note is to relate the new host for the *Aphaereta* sp. species in Brazil.

During the period from March to September 2001, 374 specimens of *Aphaereta* sp. (Hymenoptera: Braconidae) were collected in 26 pupae of *Peckia chrysostoma* (Wiedemann, 1830) (Diptera: Sarcophagidae). From the first to twelfth pupae were found 8, 10, 22, 27, 28, 29, 3l, 31, 40, 42, 47 and 60 specimens, respectively. The *Aphaereta* sp. presented himself as gregarious, emerging several individuals from the same puparia, a super parasitism is considered very ordinary.

This specie occurred as dipterous parasitoid, developed in bovine liver in typical wood areas in the state of Goiás. Therefore, this is the first register of *Aphaereta* sp. in pupae *P. chrysostoma* (Figure 10) in Brazil [19,20].

Figure 10 *Peckia chrysostoma* (Wiedemann, 1830) (Diptera: Sarcophagidae); (Source: https://sarcophagidae.myspecies.info/taxonomy/term/1873/media)

2.3. Study 2

The purpose of this note is to report the natural enemies of *Oxysarcodexia thornax* (Walker, 1849) (Diptera: Sarcophagidae) collected in human feces, fish, and bovine kidneys.

From May to July 2001, 100 pupae of *O. thornax* were collected in Itumbiara, GO, being 23 in human feces, 31 in fish and 46 in bovine kidneys (Figure 11).

Figure 11 *Oxysarcodexia s*pp., males. 254–256. *Oxysarcodexia terminalis* (Wiedemann, 1830) (Argentina, MACN). 254. Habitus, lateral view. 255. Terminalia, lateral view. 256. Terminalia, posterior view. 257–259. *Oxysarcodexia thornax* (Walker) (Brazil, São Paulo, Campinas, LIE). 257. Habitus, lateral view. 258. Terminalia, lateral view. 259. Terminalia, posterior view. 260–263. *Oxysarcodexia timida* (Aldrich, 1916) (Venezuela, Aragua, NHMD). 260. Habitus, lateral view. 261. Terminalia, lateral view. 262. *Distiphallus*, anterior view. 263. Terminalia, posterior view; (Source: Figs 254–256 by P.R. Mulieri (MACN).)

Previously, this species had been collected in the same municipality, from cattle liver and feces. The total percentage of parasitism was 57%. Regarding the parasitoids *Gnathopleura quadridentata* (Wharton, 1986) (Braconidae), *Brachymeria podagrica* (Fabricius, 1787) (Chalcididae), *Hemencyrtus* sp. and *Pachycrepoideus vindemmiae* (Rondani, 1835) (Pteromalidae) the parasitism percentage was 20%, 11%, 10% and 16%, respectively [21].

2.4. Study 3

This work presents for the first time the results of an investigation on the fauna of Sarcophagidae attracted by a pig carcass exposed in an area of Cerrado, Distrito Federal, Brazil.

A total of 4,626 Sarcophagidae were collected, with a sex ratio of approximately one male for every three females. Presents the abundance of the 28 species identified, totaling 1344 male specimens. Species of *Oxysarcodexia* Townsend accounted for 42.48% of the total. Among them, *Oxysarcodexia thornax* (Walker 1849) (Diptera: Sarcophagidae) presented the greatest abundance (Figure 12).

Figure 12 Genitalia of *Oxysarcodexy thornax* (Walker 1849) (Diptera: Sarcophagidae); (Source: https://biodar.unlp.edu.ar/sarcophagidae/en/info/20439.html)

The five stages of decomposition proposed were observed, with the fresh, swelling, deterioration and dry stages lasting one, eight, 13 and nine days, respectively. Collections were completed 14 days after entering the waste phase. Most Sarcophagidae were collected during the swelling phase. Considering both sexes, 2,947 sarcophagids (63.70) were collected in the interval between the 7th and the 14th day after the animal's death, period included in the phases of swelling and deterioration of the carcass. The population peak occurred on the 10th day after the animal's death with 509 collected sarcophagids, 11.00% of the total [22].

2.5. Study 4

Thus, this work presents an updated list of Sarcophagidae species recorded for the state of Mato Grosso do Sul.

In the present inventory, 26 species were listed for the state of Mato Grosso do Sul. To discriminate the previous records between MT and MS, the collection origins in the original bibliography were verified, which allowed to emphasize even more how under-sampled the area is. Of the 53 species recorded in, only 26 are on our list, but of these only 19 have a confirmed record for MS and seven were included because it is impossible to discriminate their origin (Figure 13).

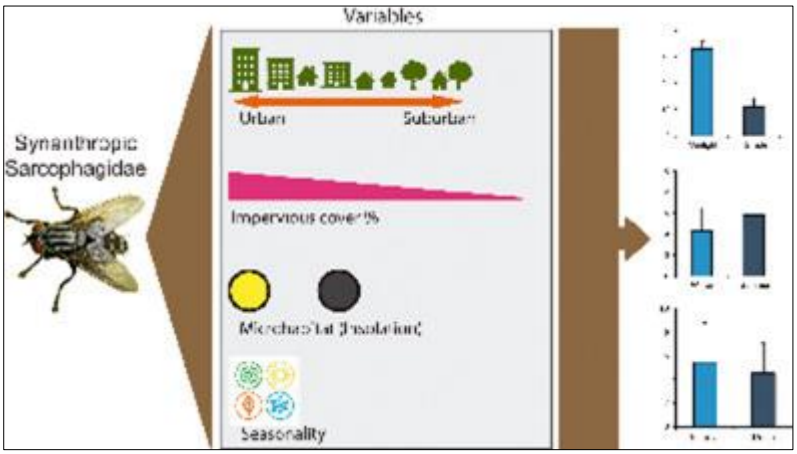

Figure 13 The urbanization process affects the structure of insect communities, favoring biotic homogenization processes by promoting adequate conditions for the establishment of synanthropic species; (Source: https://onlinelibrary.wiley.com/doi/10.1111/mve.12481)

From the, possibly because it is very numerous and because of the easy attractiveness of its species for several baits. However, result obtained, it is observed that *Oxysarcodexy* Townsend was the most diverse genus with seven species record, it is certainly under sampled in MS, since 23 species of this genus have been recorded in other areas of the Brazilian cerrado.

Likewise, we can estimate that *Peckia* Robineau-Desvoidy, a relatively numerous genera with large specimens, should be better represented in MS, as 14 species have already been recorded in cerrado, while the literature only registers four for this state. Below is the list resulting from the analysis of the literature, indicating the municipalities of MS, when possible.

Of the 26 records presented, most are due to collections carried out in Salobra, municipality of Miranda Regarding the other locations, four records are followed in Bodoquena and only one for Maracaju, Três Lagoas, Nhecolândia and, probably Bataguassu [23].

2.6. Study 5

Thus, the aim of this paper was to know the *Oxysacordexia* fauna visiting rotting pig carcasses in an Atlantic Rain Forest fragment in the Municipality of Salvador, Bahia. Four decomposing pigs' carcasses were used to attract insects, exposed in a forest fragment for two seasons: rainy (July-August / 2012) and dry (November to December / 2012).

A total of 236 male Diptera specimens of the Sarcophagidae family, belonging to the genus *Oxysarcodexia*, distributed into six species were collected: *Oxysarcodexia amorosa* (Schiner, 1868); *Diana oxysarcodexy* (Lopes, 1933); *Oxysarcodexy fringidea* Curran & Walley; *Oxysarcodexy major* Lopes (Walker, 1849) and *Oxysarcodexy timid* (Aldrich, 1916). In the case of *O. major*, this study also represents its first record for the Northeast Region (Figure 14).

Figure 14 Decomposition stages for the sunlit pig carcass (A–E) are matched with comparable stages for the shaded pig carcass (F–J) at selected observation periods in 2004; (Source: https://www.semanticscholar.org/paper/Carrion-fly-(Diptera%3A-Calliphoridae)-larval-of-and-Joy-)

The most abundant species was *O. timid*, represented by 37.3% relative abundance. This species was found both in the dry period (from the gas phase) and in the rainy period (final stages of decomposition). The species O. fringidea occurred in both periods, however, with greater abundance in the rainy season, where it was found colonizing the carcass only in the phases of advanced deterioration and remains. In the dry period, this species only did not colonize the carcass in the fresh phase. Observing other studies on the fauna of decomposing Diptera, *O. thornax* (AR=16%) was not the most abundant species.

As for the decomposition time, in the rainy period the carcass took 11 days to reach the waste phase, while in the dry period this same process lasted only 8 days. Relating the abundance data in the two sampled periods, an apparent preference of individuals of the genus *Oxysarcodexia* for the rainy season was noted, with 138 specimens collected in this period (58.4% of individuals collected throughout the experiment period) [24].

2.7. Study 6

Figure 15 *Aphaereta* sp. (Foerster, 1862) (Hymenoptera: Braconidae); (Source: https://bdj.pensoft.net/article/49017/zoom/fig/5452762/)

The objective of this work was to evaluate the occurrence of parasitoids in *Peckia chrysostoma* (Wiedemann, 1830) (Diptera: Sarcophagidae) pupae, collected in the bovine kidney substrate.

During the period from August 2003 to March 2004, 921 specimens of parasitoids were collected in 942 puparia of flies belonging to the species *P. chrysostoma* resulting in a percentage of parasitism of 97%.

The parasitoids collected were: *Aphaereta* sp. (Foerster, 1862) (Hymenoptera: Braconidae), *Hemencyrtus herbertii* Ashmead (Hymenoptera: Encyrtidae) and *Nasonia vitripennis* Walker (Hymenoptera: Pteromalidae), which presented 54.72%, 23.89% and 13.58% of the parasitism, respectively (Figure 15) [25].

2.8. Study 7

In this study, we aimed to contribute to the knowledge on the diversity and ecology of Sarcophaginae, their diet and habitat preferences, as well as their activity periods (day/night) in the Guajira biogeographic province.

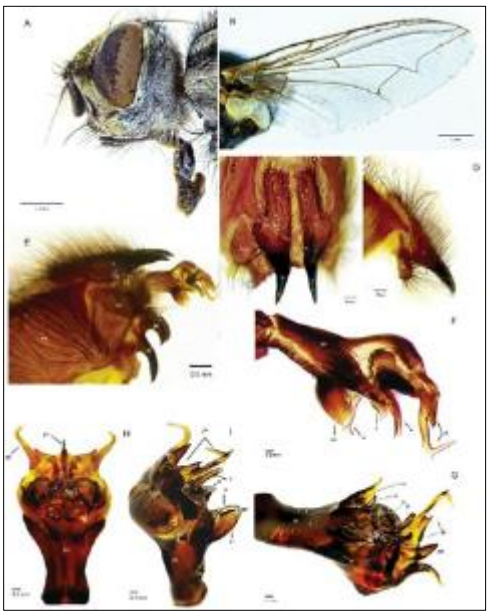

Figure 16 A head left lateral view B wing, ventral view C cerci and surstyli, dorsal view D cerci and surstyli, right lateral view E terminalia, right lateral view in glycerine F distiphallus, right lateral view in glycerine G distiphallus, right lateroventral view H distiphallus, dorsal view flipped vertically I distiphallus, right laterodorsal view flipped vertically. Abbreviations: c, fenced; ep, epandrium; h, harps; iv, inferior bladder lobe; ja, lateral juxtal arms; jm, medial part of juxta; m; membrane; po, postgonite; pp, paraphallus; pr, pregonite; s, style; su, ssurstyli; sv, upper bladder lobe; (Source: https://zookeys.pensoft.net/article/50759/zoom/fig/11/)

A total of 14,223 sarcophagines (11,094 females and 3,129 males) were collected, which belong to 28 species of nine genera. *Oxyvinia excisa* (Lopes, 1950) is a new record for Colombia. The new records increased to 97 the number of Sarcophaginae species and to 103 the number of flesh flies known to the country.

Oxysarcodexia bakeri (Aldrich, 1916), *Oxysarcodexia timida* (Aldrich, 1916), *Tricharaea occidua* (Fabricius, 1794), and *Oxysarcodexia conclausa* (Walker, 1861) were the most abundant species in urban environments. The species *T. occidua*, *Ravinia columbiana* (Lopes, 1962), *O. conclausa*, *O. bakeri*, *Ravinia effrenata* (Walker, 1861), and *Oxysarcodexia diana* (Lopes, 1933) were the most abundant in rural areas, while *O. conclausa*, *O. timida, T. occidua,* and *Oxysarcodexia amorosa* (Schiner, 1868) were the most abundant taxa in forest habitats.

Analysis between species and baits showed that *O. excisa* and *P. intermutans* were associated with feces, while *S. cuneata* showed preference for fruit. Fish was the preferred substrate for most of the species, with the following species showing strong affinity *Oxysarcodexia angrensis* (Lopes, 1933), O. avuncula, *O. bakeri*, *O. conclausa*, *O. major, O. occulta, P. anguilla, P. collusor, P. gulo, P. hirsuta, P. lambens, P. pexata* and *T. placida* (Figure 16) [26].

2.9. Study 8

The objective was to inventory the richness of Sarcophaginae in fragments of the Caatinga in Bahia and the Atlantic Forest in São Paulo, as well as to know the diversity of the subfamily in relation to the meteorological parameters of each biome and the baits by which the different species were attracted.

A total of 2,878 specimens were collected, belonging to 57 species and 18 genera, with *Oxysarcodexia*, *Dexosarcophag*a and *Helicobia* being the most abundant. Only in the Atlantic Forest biome the abundance was significantly influenced by the collection sites ($F = 13.65$; $p < 0.0001$) and seasonal period ($F = 12.18$; $p = 0.0005$) (Figure 17).

Figure 17 Species of Sarcophaginae; (Source\\; https://keys.lucidcentral.org/search/tag/sarcophaginae/)

Regarding the baits, only the abundance of *Oxysarcodexia Carvalhoi* Lopes, 1946, was significantly different when comparing bovine liver and chicken gizzards and a mixture of banana and beer ($F = 5.42$; $p = 0.0209$). In the Pearson correlation analysis between the abundances of the ten most collected species and the meteorological parameters, *Peckia* (*Sarcodexia*) *lambens* (Wiedemann, 1830) is the only species that presents a significant correlation between all the analyzed variables [27].

2.10. Study 9

Since the biodiversity may vary in different agroecosystems and it can be used to improve pest management it justifies the importance of the first record of *Peckia (Sarcodexia) lambens* (Wiedemann, 1830) (Diptera: Sarcophagidae) parasitizing *Spodoptera frugiperda* (Smith, 1797) (Lepidoptera: Noctuidae) in the state of Mato Grosso do Sul, Brazil (Figure 18).

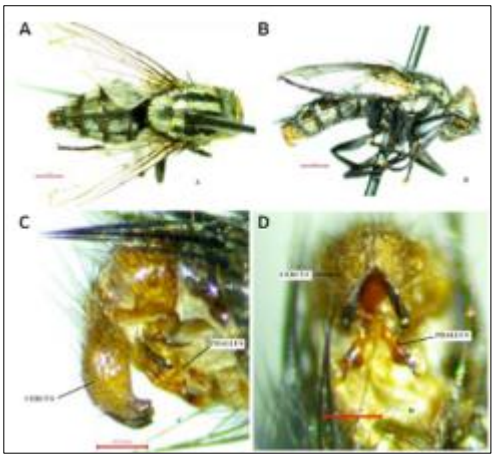

Figure 18 *Peckia (S.) lambens* (A) and (B), male habitus, dorsal and lateral views; (C) terminalia in lateral view; (D) teminalia in ventral view. SciELO - Brazil - First record of *Peckia (Sarcodexia) lambens* (Wiedemann, 1830) (Diptera:

Sarcophagidae) parasitizing *Spodoptera frugiperda* (Smith, 1797) (Lepidoptera: Noctuidae) in Brazil; (Source: hrome-xtension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?)

We collected 853 fall armyworm larvae of which eight percent were parasitized by three species of Diptera: two species of Tachinidae, *Archytas incertus* (Macquart, 1851) (61 specimens); *Winthemia trinitatis* Thompson, 1963 (seven specimens); and one species of Sarcophagidae, *P. (S.) lambens* (one specimen).

Achytas incertus and W. *trinitatis* have been recorded parasitizing *S. frugiperda* in maize crops in Brazil. *Peckia (S.) lambens* is known as parasitizing many Lepidoptera pest, *Alabama argillaceae* (Hübner, 1823), *Oiketicus kirbyi* (Gulding, 1827), *Mocis latipes* (Guenée, 1852) and *Diatrea saccharalis* (Fabricius, 1794) [28, 29, 30].

2.11. Study 10

2.11.1. Miltogrammatinae

From genus *Miltogramma*. Satellite flies: adult females may trail behind potential hosts at 15-30 cm, often keeping the distance within a very narrow range as though tethered to the wasp (like a satellite is "tethered" to its parent body). Arista usually bare or pubescent, but if short plumose, then hind coxa bare on posterior margin. Coxopleural streak present (1) (distinguishes from Sarcophaginae). Larvae of most species feed on prey captured and paralyzed by adult digger wasps (Sphecidae, i.e., Apoidea as used here); the prey may include arthropods from a variety of families and orders.

Figure 19 Digger wasps in action. 2a. Ammophila mongolensis with prey. 2b. Crabro (Anothyreus) lapponicus. 2c-d. Crabro (Anothyreus) maeklini with prey. 2e-f. Gorytes neglectus with prey. 2g. Stizus perrisi wit. Kleptoparasites of Digger Wasps (Sphecidae): female flies lay live larvae on the wasp's prey before it is buried, so the prey becomes food for the fly's larvae instead of the wasps. In some species, female flies larviposit in the entrance of wasp burrows, and the fly larvae wriggle down the burrow in search of food (Figure 19) [31].

2.12. Study 11

2.12.1. Paramacronychiinae

The Paramacronychiinae are a group of sarcophagid flies combining a non-plumose arista with strong hairs on the meron. They are diverse in habits, including necrophagous species, predators of snails and parasites of other insects (Figure 20).

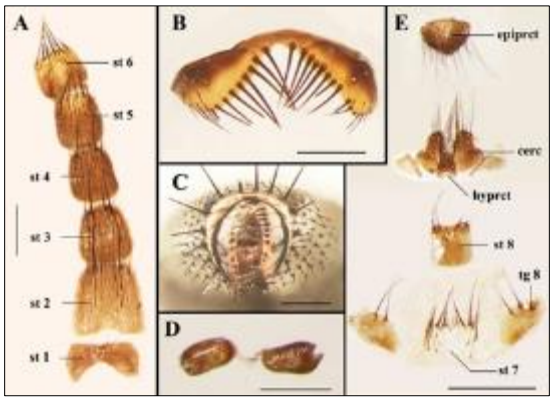

Figure 20 *Agria* (Sarcophagidae) Paramacronychiinae

Head profile with convex occipital region; antennal arista not plumose; eyes not or only slightly enlarged; postocular setae alternating in size; notopleuron without sub primary bristles; metasternal area bare; hind haunch bare posteriorly; coxopleural streak present; male midfemur with apical posteroventral ctenidium of stout, flattened bristles; male abdominal sternites 2–4 partly hidden by overlapping margins of corresponding tergites, terminalia usually protruding, with tergite 6 distinctly fused to syntergosternite 7+8 at more or less right angle.

This subfamily includes lepidopteran predators or parasitoids (*Agria*), predators on immatures (mainly prepupae) of bumblebees (*Brachycoma*) and generalist scavengers and insect predators (*Sarcophila* and *Wohlfahrtia*) [32].

3. Conclusion

The Sarcophagidae or flesh flies can carry leprosy bacilli and can transmit intestinal pseudo myiasis to people who eat their larvae. Flesh flies, particularly *Wohlfahrtia magnifica*, can also cause myiasis in animals, mostly to sheep, and can give them blood poisoning, or asymptomatic leprosy infections.

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