Bug-killing flies (Tachinidae: Phasiinae) in biological control: overcoming taxonomic problems as a starting point

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Tachinids are known for their parasitoid habit. Various attempts have been made to employ these flies for biological control, with approximately 100 tachinid species being used worldwide. The success rate varies among these attempts; however, in the few successful cases, excellent results were observed (Grenier 1988).

There are many possible reasons for these failures, mostly related to the lack of knowledge of the taxonomy, biology, and ecology of the tachinids, as well as logistical problems related to their breeding, transport and release. The taxonomic impediment and incorrect identification of the involved species and strains are well known barriers for effective biological control (Grenier 1988, Van Driesche 2004, Stireman et al. 2006). When one considers Neotropical tachinids and their long history of taxonomic problems, it is possible to observe a possible correlation between the lack of taxonomic knowledge and the limitations for biological control studies in the region (Guimarães 1977, O' Hara 2013).

Furthermore, many species of true bugs (Heteroptera) are important pests in many cultures. These pest species are difficult to control, and recently, some populations have been growing rapidly in different countries (Sosa-Gómez et al. 2019). Among tachinids, bug-killing flies (Phasiinae) are well known heteropteran parasitoids. Despite being the smallest Tachinidae subfamily, with approximately 650 species, their diversity in terminalia morphology, both male and female, is probably the most notable. This is probably related to their habit of using heteropterans as hosts, which are strongly sclerotized insects, instead of the more common soft-bodied larvae (Blaschke et al. 2018, Dios & Nihei in prep).

Numerous Neotropical phasiines have potential to be employed in biological control, with many species being observed in faunistic surveys or when breeding heteropteran pests (Agostinetto et al. 2018, Zerbino & Panizzi 2019, Aquino et al. 2020, Lucini et al. 2020). However, many species present problematic taxonomy and/or are undescribed species. Previous studies have shown that some failures in the introduction of phasiines for biological control were greatly or at least partially affected by wrongly identified species (Dios & Nihei 2017, Dios & Nihei 2020, Dios, Ziegler & Zeegers 2021). At the same time, knowing the local fauna for biological control is key for potential future applications, as using local biological control agents reduces the probability of any environmental impact and increases the chance of success (Van Driesche 2004, Lamichhane et al. 2015, Barratt et al. 2018).

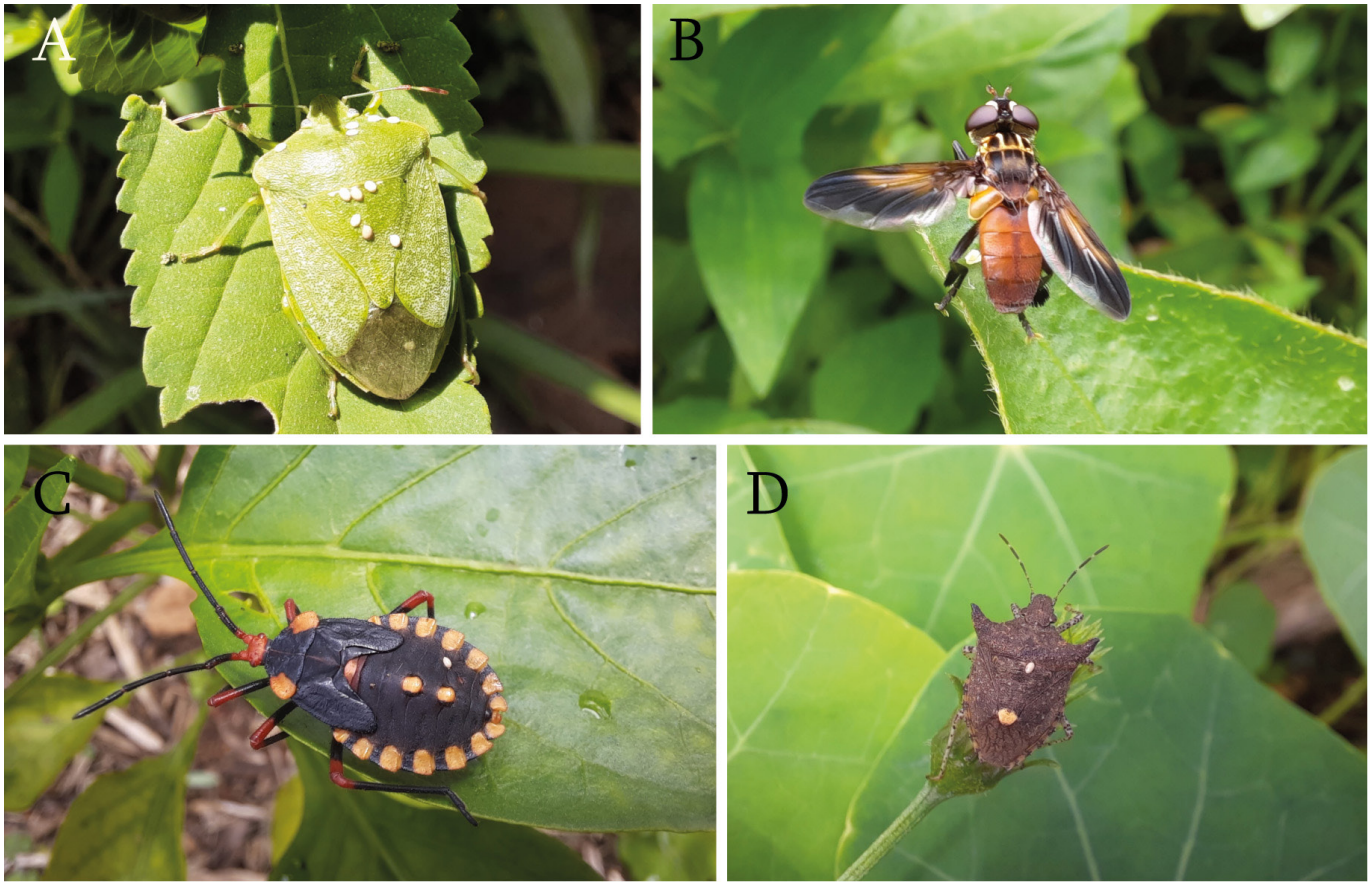

Figure 1. A. *Nezara viridula* (L.), the southern green stink bug (Pentatomidae), with *Trichopoda pictipennis* Bigot eggs. **B.** A male *T. pictipennis*. **C.** *Spartocera* sp. (Coreidae) last nymphal instar with an unidentified Gymnosomatini egg. **D.** *Euschistus* sp. (Pentatomidae) with an unidentified Gymnosomatini egg. All photographs taken in São Paulo, SP, Brazil.

Therefore, taxonomic knowledge and host relationships of Neotropical Phasiinae need to be comprehensively expanded. Aiming at this, I recently started a postdoc project approved by "Fundação de Amparo à Pesquisa do Estado de São Paulo" (FAPESP grant 2022/14482-6) which focuses on phasiine integrative taxonomy, combining important museum collections and fresh material reared from pests in different crops, with the intent to help future biological control studies and programs. The project is being developed as a collaboration between "Museu de Zoologia da Universidade de São Paulo" (MZSP) in São Paulo and "Escola Superior de Agricultura Luiz de Queiroz" (ESALQ) in Piracicaba. It is indispensable to integrate museum collections and their fundamental historical knowledge, highlighting their value for applied taxonomy and biodiversity research, while combining it with data obtained in the field.

I intend to complete taxonomic revisions of different Phasiinae groups, mainly those that parasitize heteropterans that feed on any kind of agricultural crop. I will explore the morphology extensively, including eggs and larvae, where possible, as well as sequence DNA barcodes of available specimens. For this purpose, we will use both museum specimens as well as material obtained from rearing bugs from different crops (Fig 1). A key to the genera of New World Phasiinae is in progress, new species are being described, and some genera will be synonymized. These studies will include all observed data that could help in future biological control studies; e.g., new host records, egg morphology, larval development, male/female mating behavior, and female oviposition (Fig 2).

The project already has a wide range of collaborators from different Latin American countries. It will have contributions from different ESALQ researchers, including those in the "São Paulo Advanced Research Center for Biological Control" (SPARCBio) directed by Prof. Dr. José Roberto Postali Parra, as well as researchers from "Consejo Nacional de Investigaciones Científicas y Técnicas de la Argentina" (CONICET - FCNyM, UNLP) in Argentina.

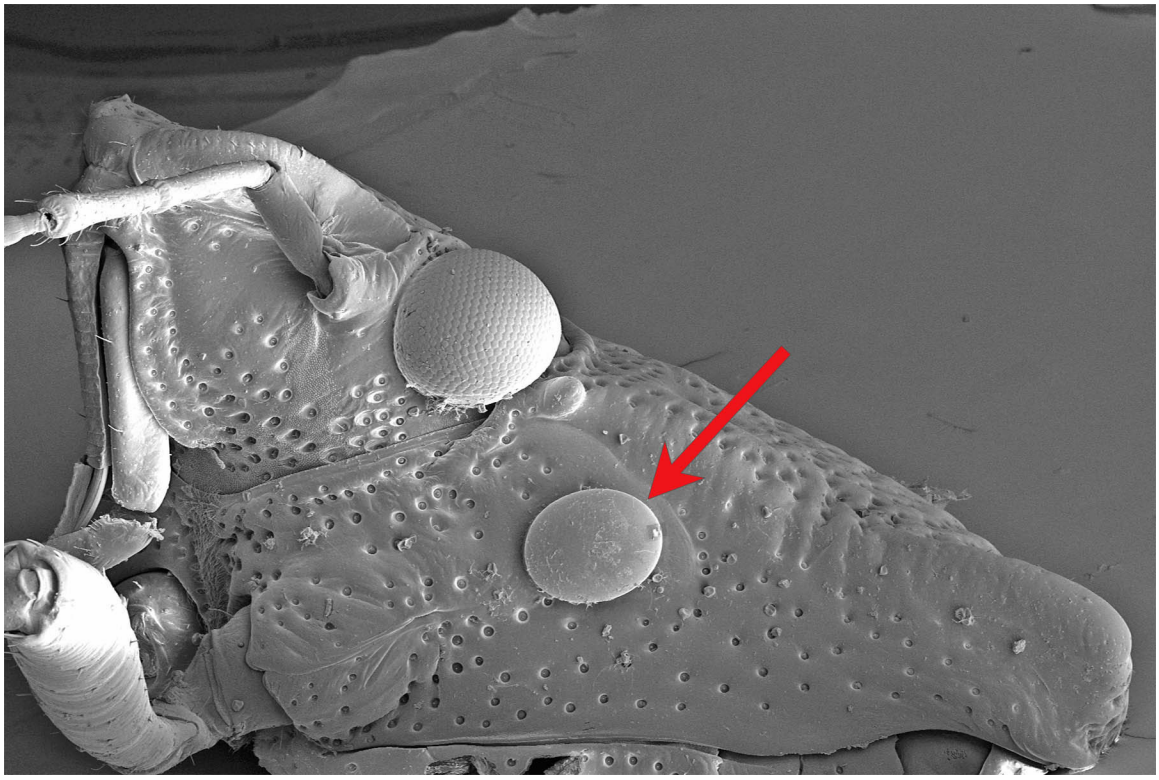

Figure 2. Scanning electron microscope image of a *Mormidea* sp. (Pentatomidae) head and prothorax with an attached *Gymnoclytia* sp. egg (red arrow).

To date, we already have some encouraging results: a probable undescribed species that has great potential for controlling one pest species, DNA barcode sequences for different phasiines, many new host records, and some data related to oviposition and larval development. I am also preparing manuscripts that deal with taxonomic synonyms, mainly in Gymnosomatini.

Concomitantly, I am studying other tachinid groups, especially when dealing with new host records and/or groups that parasitize other important insect pests. I have already received material reared from different pests all around Brazil, and I am preparing a few publications on this topic. This is easier now, as I am currently working in the MZSP, which has one of the largest and most important collections of Neotropical Tachinidae. Many tachinid experts have worked here, including José Henrique Guimarães, who was the collection curator for many years (Lamas et al. 2009). I have compiled all host data (mostly unpublished) from the collection, in addition to all tachinids with puparia, and already have more than 360 entries.

Hopefully, this project will be a starting point for new biological control studies with bug-killing flies, especially in Latin America. The correct species identification based on morphology and molecular data is crucial for future biological control programs. We expect our results will increase the chances of successful new alternatives for biological control with tachinid flies, while contributing to the taxonomy of the group as well.

If anyone has any material or data related to Phasiinae and their hosts, please feel free to contact me. Similarly, if anyone is interested in any tachinid data available at the MZSP collection, I am willing to help, as I think collaboration is key for modern science.

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