Honeydew of *Aethalion reticulatum* (Linnaeus, 1767) (Hemiptera: Aethalionidae) as a food resource for social wasps (Vespidae: Polistinae) in an urban area within the Atlantic Forest-*Cerrado* ecotone

Honeydew de *Aethalion reticulatum* (Linnaeus, 1767) (Hemiptera: Aethalionidae) como recurso alimentar para vespas sociais (Vespidae: Polistinae) em área urbana no ecótono entre Mata Atlântica e Cerrado

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Abstract: *Aethalion reticulatum* frequently forms symbiotic interactions with hymenopteran insects, however, there is little information involving social wasps. Thus, the aim of this study was to provide ecological and ethological information regarding the use of honeydew produced by *A. reticulatum* as a food resource for different species of social wasps in an urban environment, in an ecotonal region between the *Cerrado* and Atlantic Forest in southeastern Brazil. During the study, 54 individuals of 10 species of social wasps were recorded consuming honeydew produced by *A. reticulatum*. It is likely that generalizing and standardizing classifications of interactions between social wasp-hemipteran will not be possible. Nevertheless, our study provides important information: first, different species of Polistinae can simultaneously use honeydew produced by *A. reticulatum* as a food source in urban environments, and second, it contributes ethological information, with newly behavioral acts, regarding the use and competition for this food resource among social wasps.

Keywords: Etology. Ecology. Kleptobiosis. Auchenorrhyncha. Hymenoptera.

Resumo: *Aethalion reticulatum* frequentemente forma interações simbióticas com insetos himenópteros, porém há poucas informações envolvendo vespas sociais. Assim, o objetivo deste estudo foi acrescentar informações ecológicas e etológicas sobre a utilização de *honeydew* produzido por *A. reticulatum* como recurso alimentar para diferentes espécies de vespas sociais em ambiente urbano, em uma região ecotonal de Cerrado e Mata Atlântica no Sudeste do Brasil. Durante o trabalho, foram registrados 54 indivíduos de dez espécies de vespas sociais consumindo *honeydew* produzido por *A. reticulatum*. É provável que não seja possível generalizar e padronizar as classificações das interações entre vespas sociais e hemípteros, entretanto nosso estudo traz importantes informações: primeiro, diferentes espécies de Polistinae podem utilizar simultaneamente o *honeydew* produzido por *A. reticulatum* como fonte de alimento em ambiente urbano; segundo, acrescentou-se informações etológicas, com novos atos comportamentais, quanto à utilização e à competição entre vespídeos sociais por esse recurso alimentar.

Palavras-chave: Etologia. Ecologia. Cleptobiose. Auchenorrhyncha. Hymenoptera.

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INTRODUCTION

Understanding the interspecific relationships among organisms allows for the establishment of more productive and conservationist management practices in agricultural (Parada & Salas, 2023) and urban ecosystems (Prezoto et al., 2019), as it enables the comprehension and valorization of different environmental services, such as biological control (Prezoto et al., 2019) and pollination (Brock et al., 2021). This supports research aimed at clarifying ecological connections, such as the utilization of honeydew excreted by hemipterans, which serves as a food source for a variety of animal groups (Fölling et al., 2001; Davidson et al., 2003; Chamorro et al., 2013). This excretion results from the elimination of excess sugar obtained during feeding, which can be beneficial for sap-sucking hemipterans, as it attracts other insects, like ants, that protect them from their predators (Nelson & Mooney, 2022). This symbiotic relationship, named trophobiosis, has been known to confer advantages to plants, as defensive strategy against herbivores. However, it may also have drawbacks, including the potential suppression of pollinators by ant antagonism (Ibarra-Isassi & Oliveira, 2018), and possibly promoting the spread of sooty mold (Azuara-Dominguez et al., 2021).

Studies have demonstrated the use of this excretion by social wasps (Vespidae: Polistinae) in different locations around the world (Letourneau & Choe, 1987; Dejean & Turillazzi, 1992). However, these interactions are not fully elucidated, with limited information available, especially for Brazil (e.g., Ricioli et al., 2017). These social insects prey on different agricultural pests (Brock et al., 2021), including in urban environments (Prezoto et al., 2019), and have a wide geographic distribution in Brazil, such as in the *Cerrado* and *Mata Atlântica* (Souza et al., 2020a, 2020b).

Aethalion reticulatum (Linnaeus 1767) (Hemiptera: Aethalionidae), is a sap-sucking hemipteran that secretes honeydew. This species has a wide distribution in Brazil (Rando & Lima, 2010; Santos et al., 2015) and attacks different native and commercial plant species (Resende et al., 2021; Santos & Silva, 2021; Oliveira, 2024). The exudate is consumed as a food resource by stingless bees, ants and spiders (Santos & Silva, 2021; Oliveira et al., 2025). In general, the interactions established between *A. reticulatum* and hymenopterans are considered mutualistic, in which the insects offer protection to the leafhoppers in exchange for food resources (honeydew), e.g., ants (Rando & Lima, 2010), and stingless bees (Oda et al., 2009; Baronio et al., 2012; Santos & Silva, 2021). However, this interaction is not fully understood when it involves social wasps, as it can be interpreted as mutually beneficial (Letourneau & Choe, 1987) or non-mutualistic, e.g as kleptobiosis (Ricioli et al., 2017).

Thus, the aim of this study was to add information into the utilization of excretions from *A. reticulatum* as a food source for various species of social wasps in an urban setting within the transitional zone between the *Cerrado* and Atlantic Forest domains. Studies like this contribute to the elucidation of trophic interactions that depend on honeydew, especially in urbanized areas and when involving groups with limited available information, such as social wasps (Ricioli et al., 2017).

MATERIAL AND METHODS

In early January 2024, social wasps were observed visiting colonies of *A. reticulatum* (n = 6) on a *Cinnamomum verum* J. Presl tree (Lauraceae) in the urban area of Ritápolis (21° 01' 23.87" S; 44° 19' 12.09" W), in the mesoregion of Campos das Vertentes, at the ecotone between the domains of the Atlantic Forest and *Cerrado* (Oliveira et al., 2023), Minas Gerais, Southeast Brazil. Social wasp individuals were captured using an entomological net from the 10th to the 15th of the same month, for eight hours per day, divided between four hours in the morning (08:00-12:00) and four hours in the afternoon (14:00-18:00), totaling 40 hours of sampling effort. The captured specimens were sent to the *Coleção Biológica de Vespas Sociais* (CBVS) at the *Instituto Federal de Educação, Ciência e Tecnologia do Sul de Minas Gerais* (IFSULDEMINAS), Inconfidentes *campus*, where they were identified, measured, and deposited in the collection. In addition to collecting the wasps,

behavioral observation of the specimens was conducted using the ad libitum method (Del-Claro, 2010) during the same sampling period, as well as nighttime monitoring of the *A. reticulatum* colonies. *Aethalion reticulatum* was identified by Dr. Luiz Carlos Dias Rocha (IFSULDEMINAS, Inconfidentes *campus*) through photographs.

RESULTS AND DISCUSSION

Altogether, 54 individuals of ten social wasp species were recorded consuming honeydew from *Aethalion reticulatum* (Table 1).

Polybia fastidiosuscula was the most abundant wasp species with 18 individuals, corresponding to 33.33% of the total sample; *Agelaia multipicta* and *Polistes versicolor*, with two individuals each, and *Pseudopolybia vespiceps* with only one, were the least represented species. In addition to the social wasps, ants [*Camponotus* (*Myrmothrix*) *rufipes* (Fabricius, 1775), identified by Dra. Marília Maria Silva da Costa (*Universidade Federal do Rio de Janeiro* – UFRJ)] and stingless bees (*Trigona* cf. *hyalinata* Lepeletier, 1836), identified by Dra. Isabel Ribeiro do Valle (IFSULDEMINAS, Poços de Caldas *campus*) through photographs, were also recorded associated with *A. reticulatum* colonies during the daytime. Some colonies were associated with ants (n = 2) and others with stingless bees (n = 4), while during the nighttime, all *A. reticulatum* colonies were tended by ants (n = 6).

We observed two foraging behaviors of the social wasps: (1) direct collection of the secretion from the leafhoppers (Table 1, Figures 1A and 1B); and (2) collection from leaves beneath sites where the *A. reticulatum* colonies were located (Table 1, Figure 2). Despite social wasps being important predators of numerous hemipterans (Brock et al., 2021), no predation on *A. reticulatum* individuals was observed, even those that were isolated from the colony or from colonies lacking protection from ants and/or bees.

Regarding the foraging behavior of the wasps (Figure 1), two behavioral interactions (Figures 1A and 1B) were recorded: in the first one (Figure 1A), medium-sized social wasps ranging from 1.2 to 2.3 cm, such as *Pseudopolybia vespiceps*, *Polistes ferreri*, and *P. versicolor*, when approaching the colonies of *A. reticulatum*, exhibited antagonistic behaviors towards ants and bees, which were unsuccessful in driving away the social wasps. After landing on the hemipterans, the wasps apparently stimulated them with their antennae to release the honeydew (Figure 1C), as observed by Letourneau and Choe (1987) and Ricioli et al. (2017). These authors also described the behavior of *P. vespiceps*, which attacked approaching

Table 1. Species of social wasps recorded using honeydew produced by *Aethalion reticulatum* in urban environment in *Campos das Vertentes*. Legends: D = direct collection of honeydew from *A. reticulatum* individuals; I = indirect collection in vegetation near *A. reticulatum* colonies.

Tribe	Species	Abundance	Honeydew collect
Epiponini	*Agelaia multipicta* (Haliday, 1836)	2	D and I
	A. vicina (Saussure, 1854)	8	D and I
	Pseudopolybia vespiceps (Saussure, 1864)	1	D
	Polybia fastidiosuscula Saussure, 1854	18	D and I
	P. occidentalis (Olivier, 1791)	7	D and I
Polistini	*Polistes ferreri* Saussure, 1853	3	D and I
	P. versicolor (Olivier, 1791)	2	D and I
Mischocyttarini	*Mischocyttarus cassununga* (R. von Ihering, 1903)	6	D and I
	M. cf. *paraguayensis* Zikán, 1935	4	D and I
	M. rotundicollis (Cameron, 1912)	3	I
Total individuals		54	

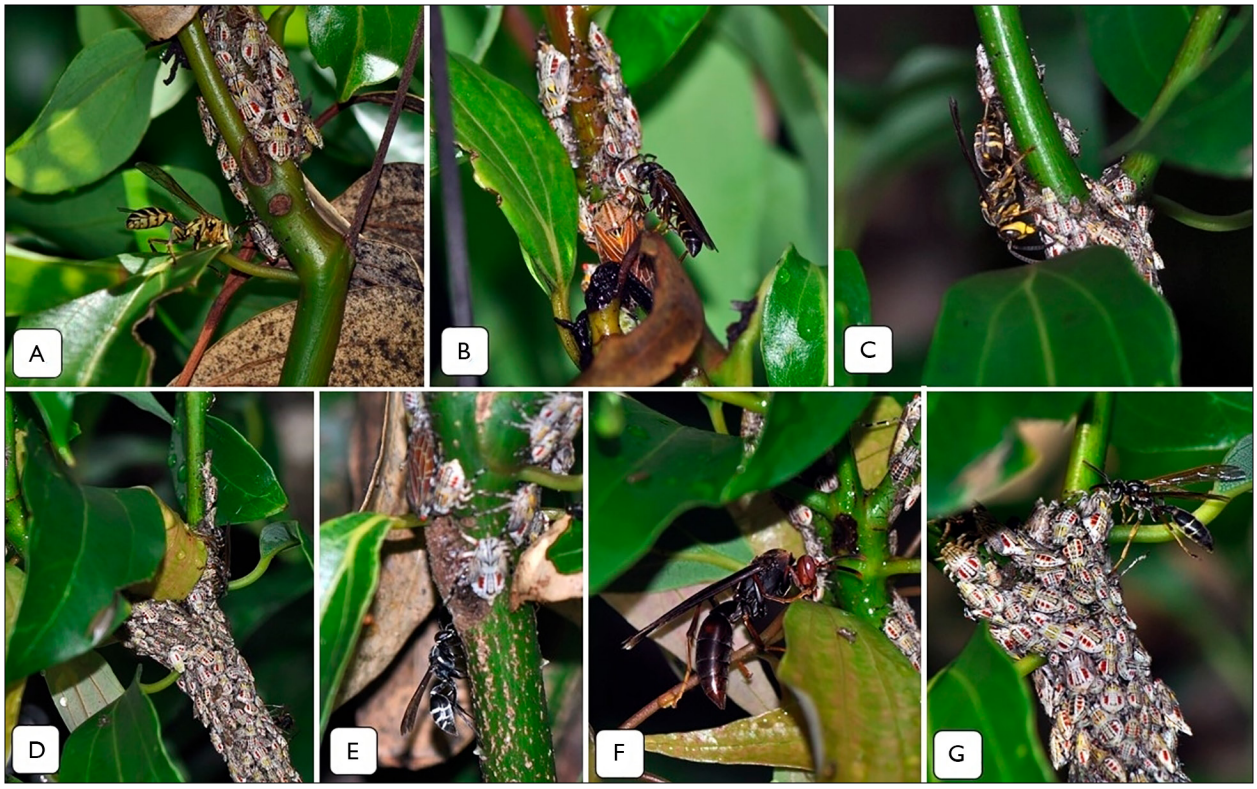

Figure 1. Social wasp species collecting *honeydew* directly from the hemipteran *Aethalion reticulatum*: A) *Agelaia multipicta*; B) *A. vicina*; C) *Pseudopolybia vespiceps*; D) *Polybia fastidiosuscula*; E) *P. occidentalis*; F) *Polistes ferreri*; G) *Mischocyttarus cassununga*. Photos: G. C. S. Oliveira (2024).

ants with 'kicks' during flight, near the leafhoppers from which they were collecting honeydew (Ricioli et al., 2017). However, we did not observe this aggressive behavior in the three species mentioned above. Instead, they used their mandibles to attack the ants and bees that approached the leafhopper colonies, like what was observed in *Synoeca septentrionalis* Richards, 1978 in Venezuela (Ramoni-Perazzi et al., 2006). In the second interaction (Figure 1B), medium-sized social wasps ranging from 0.8 to 1.1 cm (*Agelaia multipicta*, *Agelaia vicina*, *Polybia fastidiosuscula*, *Polybia occidentalis*, *Mischocyttarus cassununga*, and *Mischocyttarus* cf. *paraguayensis*) approached the colonies of the leafhoppers. However, they were immediately attacked and driven away by the ants and stingless bees. Therefore, these vespid wasps only succeeded in collecting honeydew for brief periods when the colonies were momentarily unprotected by the ants and stingless bees.

The condition described above is opposite to what was observed by Letourneau and Choe (1987) in Costa Rica, where they reported colonies of *A. reticulatum* tended by the social wasp *Parachartergus fraternus* (Gribodo, 1892), which consistently drove away the ants. The ants only succeeded in collecting honeydew directly from the leafhoppers during brief moments when the wasps moved away from the colonies or were absent.

Regarding foraging behavior 2, the ants also attacked the social wasps, even up to around 15 cm away from the leafhopper colonies. An exception to this occurred with *Mischocyttarus rotundicollis*, which, despite having a medium size of 1.8 cm, did not exhibit foraging behavior (Figures 1A and 1B), but only performing behavior 2 (Figure 2E).

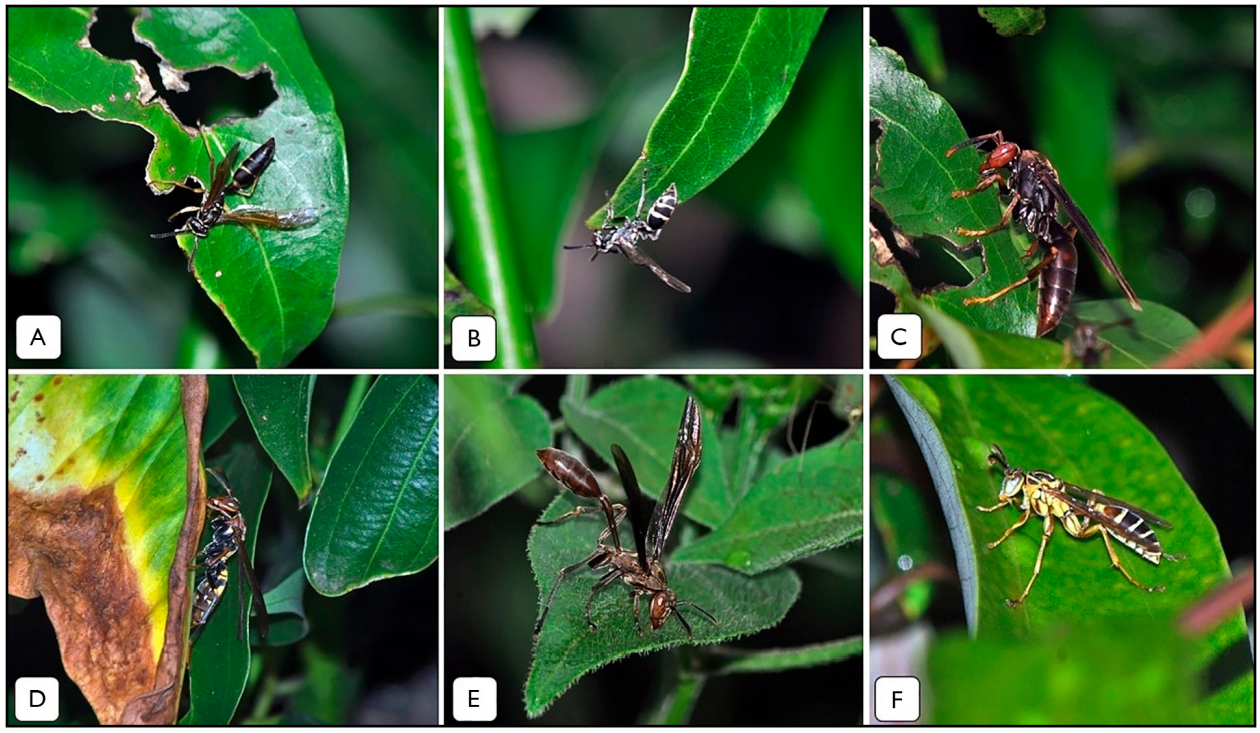

Figure 2. Social wasps collecting *honeydew* from vegetation near the colonies of *Aethalion reticulatum*: A) *Polybia fastidiosuscula*; B) *P. occidentalis*; C) *Polistes ferreri*; D) *P. versicolor*; E) *Mischocyttarus rotundicollis*; F) *M.* cf. *paraguayensis*. Photos: G. C. S. Oliveira (2024).

The interaction here described appears to be an ecological interaction of kleptobiosis (kleptoparasitism), both in the case of larger social wasps that drive away ants and stingless bees, as in the case of smaller social wasps that opportunistically consume honeydew only when the bees and ants were not present. This may occur because the aggressive and opportunistic behavior of the social wasps towards the stingless bees and ants may harm *A. reticulatum*, as the consumption of honeydew by the wasps occurs without any protection provided to the leafhoppers, as suggested by Ricioli et al. (2017). Another possibility would be a commensal relationship, in which the wasps simply take advantage of honeydew droplets released in the vegetation nearby *A. reticulatum* colonies, resulting in honeydew consumption without apparent harm or benefit to the leafhoppers, as suggested by Castro (1975) for some stingless bees of the genus *Trigona*.

Symbiotic interactions involving the collection of honeydew by social wasps from Hemiptera are relatively well-documented in the literature and occur with different species of wasps and taxa of leafhoppers, such as Membracidae, Coccidae, Kermesidae, and Cercopoidea (Belt, 1874; Jeanne, 1972; Jiron & Salas, 1975; Schremmer, 1978; Barrows, 1979; Wood, 1984). However, there are few reports of this association involving *A. reticulatum*, for example, for *P. fraternus* (Letourneau & Choe, 1987), *Pseudopolybia compressa* Saussure, 1863 (Brown, 1976), *P. vespiceps* (Ricioli et al., 2017), *Synoeca septentionalis* Richards, 1978 (Ramoni-Perazzi et al., 2006), and *Polistes erythrocephalus* Latreille, 1813 (MacCarroll & Reeves, 2004).

This type of association is considered stochastic (Letourneau & Choe, 1987) and can represent an important source of nutrition for social wasps, especially in urban environments. Although available studies have recorded a few species involved in these interactions,

our study corroborates Letourneau and Choe (1987) who consider that these interactions with hemipterans often involve a multi-species complex of social wasps. *A. multipicta*, *A. vicina*, *P. fastidiosuscula*, *P. occidentalis*, *P. ferreri*, *P. versicolor*, *M. cassununga*, and *M.* cf. *paraguayensis* represent unpublished records of the use of honeydew as a food resource, which corroborates with the generalist and opportunistic feeding habits of these insects (Richter, 2000; Prezoto et al., 2019).

CONCLUSIONS

It is likely that applying standard classifications of symbiotic interactions between insects for the suborder Auchenorrhyncha and social wasps (mutualistic, non-mutualistic, or others) may not be possible, as each interaction contains a particular context that depends on the involved wasp species. Therefore, our study provides important insights: first, different species of Polistinae can simultaneously use the honeydew produced by *A. reticulatum* as a food source in urban environments in the ecotonal area between the *Cerrado* and Atlantic Forest domains; second, it added ethological information, with new behavioral acts, regarding the utilization and competition for this resource exhibited by social wasps.

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AUTHORS' CONTRIBUTION

G. C. S. Oliveira contributed to research, conceptualization, data curation, methodology and writing (original draft, review and editing); F. G. A. Crispim contributed to writing (original draft, review and editing); D. S. Vilela contributed to writing (original draft, review and editing); and M. M. Souza contributed to conceptualization, data curation and writing (original draft, review and editing).