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SHORT COMMUNICATION

Predatory behavior of *Pseudodorus clavatus* (Diptera, Syrphidae) on aphids tended by ants

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ABSTRACT. Predatory behavior of *Pseudodorus clavatus* (Diptera, Syrphidae) on aphids tended by ants. In this study, we examined the interactions between myrmecophilous aphids, their ant-guards and a predatory syrphid species, *Pseudodorus clavatus* (F.). Larvae of this predator were found in the colonies of three aphid species: *Aphis gossypii, A. spiraecola* and *Toxoptera* sp., which were tended by eight ant species, especially *Camponotus*. Hoverfly larvae managed to infiltrate the aphid colonies and consume nymphs. Predator larvae exhibited inconspicuous movements and were not detected by ants which were commonly observed touching and antennating the larvae they come into contact. These results suggest that behavioral and chemical cues are involved in the infiltration and on the successful predation of syrphids upon aphids.

KEYWORDS. Cerrado; myrmecophilous aphids; predation; syrphid.

Ants are well known for their mutualistic associations with trophobiont insects, especially hemipterans. These interactions are beneficial for both species involved, as ants receive honeydew and in turn, protect the trophobiont herbivore against predators and parasitoids (Del-Claro & Oliveira 2000; Stadler & Dixon 2008). In the case of aphids, ants protect them from a wide range of natural enemies including coccinelids, lacewings, midges, spiders, parasitoids and hoverflies (see in Almohamad *et al.* 2008). Hoverflies (Diptera, Syrphidae) are mostly aphidophagous (Gilbert *et al.* 1994) and good models in studies of top-down forces (Dziock 2005). Although aphid-hoverfly interactions have been addressed in many studies, especially concerning oviposition patterns and biological control (Sadeghi & Gilbert 2000; Almohamad *et al.* 2009; Bergh & Short 2008), little is known about the relationships between myrmecophilous aphids, their associated tending ants and predatory hoverflies (Renault *et al.* 2005). The hoverfly *Pseudodorus clavatus* (Fabricius, 1794) is widespread in South America and is an important natural enemy of several aphids (Auad 2003). This species was recently observed in *Struthanthus polyanthus* Martius (Loranthaceae), in aphid colonies tended by ants. In this context, the aim of this study was to examine the interaction among *P. clavatus*, aphid species and tending ants, as well to detail the predatory behavior of this hoverfly on myrmecophilous aphids in a neotropical savanna. The Cerrado biome is a global hotspot which supports high levels of diversity of fauna and flora, but so far little is still known about the underlying mechanisms controlling and affecting insect-plant and insect-insect interactions (Del-Claro & Torezan-Silingardi 2009). In the present study we then examined i) possible antagonistic interactions between *P. clavatus* and ants (attack or predation); and ii) whether hoverflies showed defenses against ant contact or attack.

Fieldwork was conducted in September 2012 in a cerrado savanna reserve in Uberlandia, Brazil (400 ha; 18°59'S, 48°18'W). In the cerrado, *S. polyanthus* is a generalist hemiparasitic plant, occurring in association with several hosts (e.g., *Kielmeyera coriacea* Martius, *Pouteria ramiûora* (Martius) Radlkofer and *Styrax ferrugineus* Nees et Martius) (Arruda *et al.* 2006). We initially search the aphids in 70 individuals of *S. polyanthus*, but these insects were found in 16 plants only (22.85%). These 16 individuals of *S. polyanthus* were then tagged and observations of hoverfly-aphid-ant interactions were performed on three occasions: September 10, 18 and 28. Aphid aggregations were defined as colonies per inflorescence (sensu Yao & Akimoto 2009). The observations of hoverfly-aphid-ant interactions were performed in 15 min weekly sessions for each plant (sensu Völk 1995). Observations were performed *ad libitum* in the morning (08:00h to 12:00h) of sunny days. In order to investigate the aphid-ant-hoverfly interactions, in each observation session we carefully examined the behavior of each species involved, especially hoverflies. We were particularly interested in determining whether i) syrphids attack aphids tended by ants and ii) ants would notice presence of syrphids and attack them. At the end of the study, insects (ants, aphids and hoverflies) were collected for identification.

Pseudodorus clavatus was found in colonies of three aphid species: *Aphis gossypii* Glover, 1877, *A. spiraecola* Patch, 1914 and *Toxoptera* sp. All these aphid species were attended by ants. *Pseudodorus clavatus* was found in 92.3% (n = 12) of ant-aphid associations (Table I). No overlap among ant species in a given aphid colony was observed. *Camponotus* was the most diverse (four species) and frequent ant genus in *S. polyanthus* (in 12 of 16 plants with aphids). For instance, *C. crassus* was present in 50% of plants with aphids (n = 8), whereas *Brachymyrmex* sp. was observed in only 6% of plants with aphids (n = 1). When aphid colonies were small (< 10 nymphs), tending ants usually abandoned the aphids for a while to forage on the plant. On these occasions, *P. clavatus* larvae were observed to move towards aphids, infiltrate the colonies (n = 6 observations) and prey upon unattended nymphs. Only nymphs were attended by ants regardless of aphid colony size, small or large. Three from six observations resulted in predation. When aphid colonies were large (> 20 nymphs), ants tended aphids for longer periods. In these cases, infiltrated hoverfly larvae remained motionless (n = 10 observations), but ants were commonly observed antennating their bodies. Antennation on larvae of *P. clavatus* was performed by *C. blandus* (n = 4 observations), *C. crassus* (n = 4), *C. trapeziceps* (n = 1) and *Crematogaster bruchi* (n = 1) (see *C. crassus* in Fig. 1). Nymphs attacked by *P. clavatus* remained immobile and no reaction was observed from the neighboring nymphs in the colony. Ants were also not observed to interrupt the feeding activity of hoverflies. The predatory behavior of *P. clavatus* towards aphids was recorded in the following associations: *A. gossypii* tended by *C. blandus* (n = 1 record); *Toxoptera* sp. tended by *C. crassus* (n = 1); *A. spiraecola* tended by *C. blandus* (n = 1). For the other hoverfly-aphid-ant associations (Table I), aphids were not observed to be preyed upon by *P. clavatus*. Among all the syrphids observed (n = 16) co-occurring with aphids, 62.5% (n = 10 larvae) of them were antennated by ants whenever they approached the aphid colonies. These larvae were infiltrated in colonies of the three aphid species: six larvae associated with *A. spiraecola,* three with *A. gossypii* and one with *Toxoptera* sp.

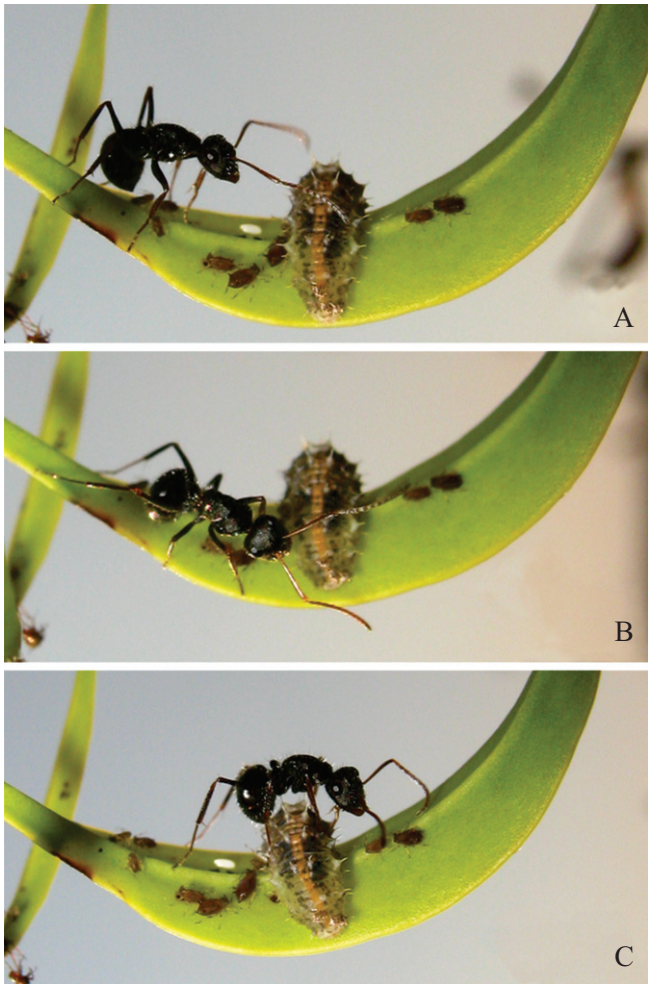

Fig. 1. An individual of *Camponotus crassus* close to a *Pseudodorus clavatus* larva (A); antennating the larva (B) and walking upon the larva (C). Ant size is approximately 5 mm.

Some aphid predators can forage in myrmecophilous aphid colonies without being attacked, presumably because

Table I. Ant species associated with aphids in *Struthanthus polyanthus* (Loranthaceae), and the occurrence of *Pseudodorus clavatus* according to ant and aphid species.

Ant species	Aphid species					
	Aphis gossypii		*A. spiraecola*		*Toxoptera* sp.	
	Ants	Hoverfly	Ants	Hoverfly	Ants	Hoverfly
Formicinae						
Brachymyrmex sp.	yes	yes	–	–	–	–
Camponotus blandus (Smith, 1858)	yes	yes	yes	yes	–	–
Camponotus crassus Mayr, 1862	yes	yes	yes	yes	yes	yes
Camponotus leydigi Forel, 1886	yes	yes			–	–
Camponotus trapeziceps Forel, 1908	–	–	yes	yes	–	–
Myrmicinae						
Cephalotes pusillus (Klug, 1824)	yes	–	yes	yes	–	–
Crematogaster bruchi Forel, 1912	–	–	–	–	yes	yes
Ectatomminae						
Ectatomma tuberculatum (Olivier, 1792)	yes	yes	yes	yes	–	–

they use specific behavior and chemical camouflage (*e.g.*Völkl 1995; Del-Claro & Oliveira 2000). *Syrphus ribesii* (Linnaeus, 1758) is an example of hoverfly that presents chemical camouflage similar to its aphid prey (Lohmann *et al.* 2006). In our study, we recorded *P. clavatus* infiltrating and preying on myrmecophilous aphids tended by aggressive ant-guards. The hoverfly exhibited similar behavior to the aphidophagous coccinellid *Platynaspis luteorubra* (Goeze, 1777) (Völkl 1995). Larvae of both species present inconspicuous movements on ant presence that may help to prevent visual detection by ants. Although chemical analyses are necessary to confirm the chemical camouflage by larvae of *P. clavatus,* we suggest that chemical cues are probably involved in predatory behavior of this hoverfly since its larvae were not attacked by ants which were commonly observed antennating their bodies. According to Sadeghi and Gilbert (2000), studies concerning the adaptations of syrphids to aphid defenses, especially myrmecophilous species, are fundamental for a better understanding of the evolution of Syrphidae. In this sense, our study contributes with information about the behavior of a common aphidophagous syrphid and its myrmecophilous preys, and consequently can aid the implementation of biological control strategies, since many aphids are crop pests.

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