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SHORT COMMUNICATION

Aphidophagous Parasitoids can Forage Wheat Crops Before Aphid Infestation, Parana State, Brazil

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ABSTRACT. Aphid parasitoids are common in Brazilian wheat fields, and parasitize aphids at the wheat tillering stage. However, there is little information available about when this natural enemy occurs in wheat crops. This study investigated the initial occurrence of aphid parasitoids in four commercial wheat crops in northern Paraná during the 2009 crop season. We installed two Malaise traps at each wheat farm, and 400 tillers were assessed weekly in each field for aphid abundance. During this study, we captured 4,355 aphid parasitoids and 197 aphids. Three species of braconid parasitoids were identified, including *Aphidius colemani* (Viereck 1912), *Lysiphlebus testaceipes* (Cresson 1880), and *Diaeretiella rapae* (McIntosh 1855). The aphids species identified were *Rhopalosiphum padi* (Linnaeus 1758) and *Sitobion avenae* (Fabricius 1775). This study showed that aphid parasitoids are present in wheat crops even when aphid densities are low, and in one farm, occurred before the aphids colonization. These reports can justified the high efficiency of these natural enemies against aphids in wheat fields.

Key Words: Microhymenopterans, population dynamics, natural biological control, wheat pests, Aphidiinae

Aphidophagous parasitoids, which are found in many regions of the world, help to regulate aphid populations in wheat crops (Adisu et al. 2002, Schmidt et al. 2003, Saethre et al. 2011, Plećaša et al. 2014, Elliot et al. 2014, Zhao et al. 2014). In temperate regions, is common aphids sexually reproduce during severe winters, and the female aphids usually lay their eggs on primary (harboreus) host plants (Starý and Havelka 2008). Sexual reproduction is a winter survival strategy because the eggs can endure the winter conditions. However, when the temperature begins to rise, the nymphs eclode and the young aphids migrate to the wheat, usually from the flowering stage onward (Schmidt et al. 2003, Thies et al. 2005, Caballero-López et al. 2012). In temperate regions, natural enemies such as aphidophagous parasitoids can survive winter in two ways: by starting diapause or by migrating to warmer regions (Jones et al. 2008). However, both these processes mean that these natural enemies need a long time to colonize wheat crops, which hinders initial aphid suppression.

However, the warmer climate in tropical and subtropical regions is more favorable to aphid development, and aphid reproduction is often asexual (thelytokous parthenogenesis) (Simon et al. 2002). This implies that there is a different dynamic spatial and temporal relationship between aphids and their natural enemies in tropical and temperate zones. In Brazilian fields, most studies have investigated the occurrence of aphid parasitoids in a field by measuring the number of mummies (Ronquin et al. 2004, Alves et al. 2005, Macedo et al. 2010). However, this method severely restricts the understanding of the behavior of these natural enemies in the field. Many studies conducted in Brazil have shown that parasitized aphids (mummies) appeared during the tillering stage (Alves et al. 2005, Machado and Santos 2013), usually parasitized by polyphagous parasitoids (Starý et al. 2007). So, it is possible that this earlier occurrence and the broad spectrum of hosts, was the main reason that biological control was quite successful.

Therefore, we believe that this natural enemy is present in the field immediately after aphid infestation. In this sense, to better understand it, this work aimed investigated when aphidophagous parasitoids colonizes wheat crops, in Parana State, Brazil. To confirm this hypothesis, we used traps that were designed to capture parasitoids, which allowed us to estimate the moment that aphid parasitoids appeared in wheat fields. This enabled us to evaluate the incidence and colonization of aphid parasitoids during the initial wheat development phase.

Materials and Methods

The study was carried out in four commercial wheat crops in northern Paraná State, Brazil, during the 2009 season (usually around April/May to August/September). The sites were located in the municipalities of Ibiporã: San Antonio Farm (SAF, 23° 14′34″ S, 51° 27′07″ W), Ibiporã Bonsucesso Farm (BF, 23° 12′26″ S, 51° 03′51″ W), Rolândia-Gioconda Farm (23° 23′59″ S, 5° 19′01″ W), and Londrina (23° 19′49″ S, 51° 08′12″ W), and the area of study (ha) was 2.3, 16.2, 20.9, and 11.4 ha, respectively. According to Köeppen's classification, the regional climate where the experiment was conducted is characterized as humid subtropical (Cfa). During the study, the mean (day/night) temperature was 20.54°C ± 1.45°C. The data were collected over 24 h by the meteorological station at the Instituto Agronômico do Paraná (IAPAR).

In all the fields, wheat (*Triticum aestivum* L.) was sown in succession to soybean [*Glycine max* (Merrill) L.]. The crop was sown on April 29 (Rolândia), May 6 (Ibiporã-FBS), May 8 (Ibiporã-SAF), and May 11 (Londrina). The landscape complex around each farm is described in Table 1. To better support the work, the description was made considering the dispersal ratio of Aphidiinae parasitoids (2 km) (Thies et al. 2005). All fields wild radish (*Raphanus raphanistrum* L.) and black-jack (*Bidens pilosa* L.), however it was not quantified.

Aphid infestation was assessed by demarcating two transects (90 m in length) per field, which were spaced 500 m apart. The transects were set up immediately after emergence (stage V1) of the wheat crops in all fields, except in Londrina, which was demarcated 1 day after sowing. Each transect contained 10 evaluation points, where 20 tillers per point were randomly evaluated ($n = 400$ tillers/assessment in each field). All the aphids were quantified and identified to the species level. Aphidophagous parasitoid colonization was monitored using Malaise traps, which were placed in the center of each transect ($n =$ two traps/field). The traps were made of a synthetic material and were shaped like

Table 1. Area total (ha) and relative (%) of crops and non-crops until 2 km around the four fields studied in northern Parana, from May to June 2009

Occupation classes	Farms							
	Ibiporã-Santo Antônio farm		Ibiporã—Bonsucesso farm		Rolândia Gioconda farm		Londrina*	
Non crop fields[1]	314.16	(25)	203.58	(16.2)	446.11	(35.5)	490.09	(39)
Cofee crop	84.19	(6.7)	36.44	(2.9)	257.61	(20.5)	69.12	(5.5)
Maize crop	87.96	(7)	333.01	(26.5)	56.55	(4.5)	126.92	(10.1)
Wheat crop	595.65	(47.4)	671.04	(53.4)	492.6	(39.2)	566.69	(45.1)
Fallow[2]	38.96	(3.1)	–	–	–	–	–	–
Oleraceous crop	41.47	(3.3)	–	–	–	–	–	–
Semi-hevergreen crop[3]	7.54	(0.6)	–	–	–	–	–	–
Buildings	86.71	(6.9)	12.57	(1)	3.77	(0.3)	3.8	(0.3)

[1]Non crop fields: included forest fragments and pasture. [2]Fallow areas: predominance of wild radish (*Raphanus raphanistrum*). [3]Semi-hevergreen crops: passion fruit (*Passiflora edulis*) and chayote (*Sechium edule*). *, farm without a name.

Table 2. Abundance total and relative (%) of aphids in four wheat fields during the tillering stage ($n = 400$ tillers/assessment). northern of Parana State, from May to June 2009. N = number of assessments during the study

Aphids	Ibiporã		Rolândia	Londrina* ($N = 7$)	Total
	Bonsucesso farm ($N = 7$)	Santo Antônio farm ($N = 7$)	Gioconda farm ($N = 4$)		
Sitobion avenae	0 (0.00%)	19 (12%)	0 (0%)	4 (100%)	23 (12%)
Rhopalosiphum padi	22 (100%)	145 (88%)	7 (100%)	0 (0%)	174 (88%)
Total	22 (100%)	164 (100%)	7 (100%)	4 (100%)	197 (100%)

*, farm without a name.

a tent with an opening at the bottom that intercepted the insects during flight after they had collided with one of trap's septa. This type of trap is very efficient for capturing parasitoids, because after they collide with one of the septa, they go to the raised end where they are trapped in a collecting vessel (bottle). The traps allowed us to record the earliest occurrence of parasitoids in wheat fields. The traps were installed and positioned such that they faced north—where the most sunlight was received. Each trap was ~1.80 m high by 1.80 m long. The collecting bottle contained 70% alcohol, which was changed weekly on the day on which the number of aphids was counted. Is important consider that this trap allow to capture parasitoids during dispersal flight among the patches. In the laboratory, the material collected was screened, and the aphidophagous parasitoids were identified using a stereoscope microscope according to the method described by Kavallieratos et al. (2006) and Pereira and Salvadori (2005).

Infestation by aphids and colonization of their parasitoids began 7 days after the wheat was sown, except at Londrina where the assessment began 1 day after the wheat was sown. The assessments were carried out on a weekly basis, and aphid species were identified using a guide developed by Salvadori and Tonet (2001). To reduce interference, insecticides were not applied up to a distance of 5 m from the evaluation points.

Finally, the data were descriptively analyzed and illustrated to depict the seasonal dynamics of aphids and aphid parasitoids.

Results

In total, 197 aphids were quantified in four areas. The major species were *Rhopalosiphum padi* (Linnaeus 1758) (88%) and *Sitobion avenae* (Fabricius 1775) (12%) (Table 2). The Malaise traps captured 4,355 parasitoids (Braconidae: Aphidiinae), and the major species were *Aphidius colemani* (Viereck 1912), *Lysiphlebus testaceipes* (Cresson 1880), and *Diaeretiella rapae* (McIntosh 1855) (Table 3). These aphid parasitoids were found at all sites examined and at each assessment (Fig. 1).

In general, aphid parasitoids occurred even in low aphid infestation (Fig. 1). Unexpectedly, the Malaise traps captured 34 parasitoids before wheat emergence in Londrina. The species captured were *L. testaceipes* ($n = 26$) and *D. rapae* ($n = 8$). Larger numbers of parasitoids were captured at Ibiporã-BF ($n = 3,418$), although only 22 aphids were reported.

Discussion

Our results showed that aphid parasitoids can forage wheat fields even in a low aphid infestation, and sometimes in absence of aphids. This observation helps us to understand the biodynamics of aphidophagous parasitoids and can be explained by two hypotheses. First, the tropical climate in northern Parana State probably means that the parasitoids can survive actively (parasitizing) for a longer period. For example, the temperature during the assessments (around $20.54°C \pm 1.45°C$) was optimal for the development of aphidophagous parasitoids (Jones et al. 2003, Rodrigues et al. 2004, Sampaio et al. 2005). Thus, the tropical climate in northern Parana allows aphidophagous parasitoids to appear in crops immediately after wheat emergence. Second, their polyphagous habit probably plays an important role in the maintenance of these parasitoids in fields because they can survive by attacking aphids from other plants such as weeds or other crops cultivated near wheat fields.

The parasitoids captured in this study (*L. testaceipes*, *A. colemani,* and *D. rapae*) can parasitize a range of aphids, which occur in a several cultivated plants and weeds (Starý et al. 2007, Tepa-Yotto et al. 2013, Macedo et al. 2010, Hollingberya et al. 2012). Therefore, although aphid infestation in the fields was low, these parasitoids survived because of the presence of alternative aphid hosts. These included weeds such as wild radish (*R. raphanistrum*) present in all areas as well as maize fields (Table 1) cultivated around the fields studied. These plants can favor the presence of aphid parasitoids due the presence of aphids hosts, which facilitates the migration of aphid parasitoids to wheat fields. So, although the neighbor plants were not investigated, this hypothesis can explain the recordings at Londrina, where *D. rapae* and *L. testaceipes* were captured before wheat emergence.

Other important factor is that the *L. testaceipes* parasitoid species, in particular, showed a low capacity to locate the host, since it has a

Table 3. Abundance total and relative (%) of aphidophagous parasitoids (Braconidae: Aphidiinae) captured in Malaise traps located in four wheat fields in northern Parana, from May to June 2009. *N* = number of collections during the study

Aphid parasitoids	Ibiporã		Rolândia	Londrina* (*N* = 7)	Total
	Bonsucesso farm (*N* = 7)	Santo Antônio farm (*N* = 7)	Gioconda farm (*N* = 7)		
Lysiphlebus testaceipes	616 (18%)	278 (53%)	112 (80%)	208 (78%)	1,214 (27.9%)
Diaeretiella rapae	205 (6%)	248 (46.3%)	7 (5%)	46 (17%)	506 (11.6%)
Aphidius colemani	2,597 (76%)	4 (0.7%)	21 (15%)	13 (5%)	2,635 (60.5%)
Total	3,418	530	140	267	4,355

*, farm without a name.

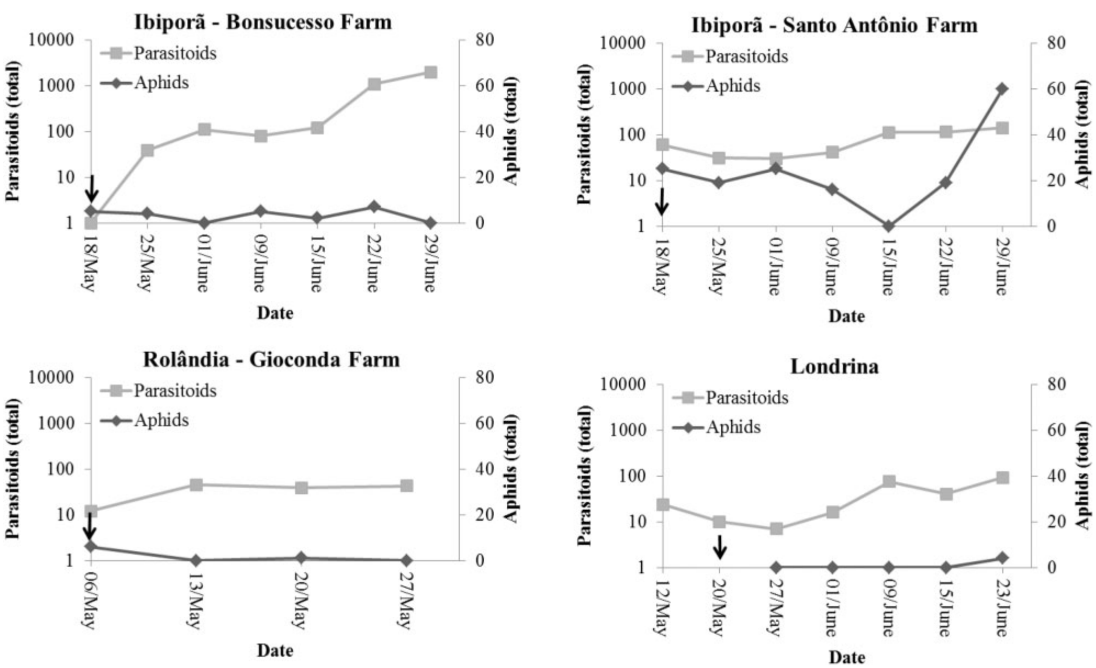

Fig. 1. Seasonal abundance of aphids and aphid parasitoids (Braconidae: Aphidiinae) (Log_{10} scale) in wheat fields located in northern Parana, Brazil, between May and June 2009. Black arrow indicates wheat emergence timing.

limited response to volatiles released by the plants (Lo Pinto et al. 2004, Fauvergue et al., 2006). Therefore, this species in a plant with no wheat aphids may be captured owing to theirs disorientation or during transit, while they searched for hosts in other crops. In contrast, *D. rapae* responds strongly to volatiles emitted by brassica plants, even in the absence of hosts (Blande et al. 2007), which suggests that their natural occurrence is related to the presence of wild radish, inside the wheat fields.

The 'early' reports of aphidophagous parasitoids in this study are very important for biological control, and it explains the high efficiency of these natural enemies in the regulation of aphid abundance. Finally, this exploratory investigation suggests that these natural enemies are well established in local agroecosystems owing to the large number of alternative hosts that are available during the growing season. Further studies into the behavior of these natural enemies in different climate and regions around the world are needed for efficient conservation of these agents of biological control.

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