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EFFECTS OF THE PESTICIDES CHLORPYRIPHOS, METSULFURON-METHYL, AND THIAMETHOXAM ON ANT COMMUNITIES IN WHEAT CROP

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Abstract

Ants are important components of food webs in several ecosystems. In anthropic areas, they can be used as bioindicators of the environmental impacts caused by many factors or in the evaluation of the dynamics of the recovery of an area after a certain disturbance. In this context, ants can be used as bioindicators in studies on the evaluation of environmental disturbances caused by pesticide use. Thus, the present work investigated the environmental impacts caused by the application of the insecticides chlorpyriphos and thiamethoxam and the herbicide metsulfuron-methyl in the community of ants in wheat crop (*Triticum aestivum* L.). The data were collected by pitfall traps and Berlese funnels. A Principal Response Curve was used for a relative abundance analysis. In addition, diversity index and richness were calculated for ant communities. The presence of six families, 11 tribes, 15 genera, and 19 morphospecies of ants belonging to the guilds of fungivorous, omnivorous, and predaceous ants were observed in the soil of the wheat crop. The insecticides chlorpyriphos and thiamethoxam reduced the richness, diversity, and relative abundance of ants of all the guilds on the surface and inside the soil. The effect of the herbicide metsulfuron-methyl on the community of ants was lower than the impact of the insecticides on these insects.

Keywords: Formicidae. Herbicide. Insect. Insecticide. *Triticum aestivum*.

1. Introduction

Ants present a wide geographical distribution and can be found in temperate and tropical climate regions, in many habitats, with a variety of food habits and defense strategies (Hölldobler and Wilson 1990; Lach et al. 2009). Their social behaviour, together with their small size, makes it easy for them to achieve food and nest in inaccessible sites (Fowler 1996).

As for their food habit, ants can be predaceous, fungivorous, or omnivorous. Predaceous ants are generalists and feed on numerous types of prey. They are important components of food webs in several ecosystems, such as crops, in which they are important agents of biological control for pests (Lach et al. 2009; Drummond and Choate 2011).

The fungivorous species are pests for several cultures (Montoya-Lerma et al. 2012; Mueller 2012). Omnivorous ants feed on sugars of plant nectarines, sugary excreta produced by insects or small prey animals, or feed on the corpses of animals (Fowler 1996).

Ant communities act as control agents of several pests in different agroecosystems (Drummond and Choate 2011). Therefore, pesticide inputs can change the richness and composition of the ant fauna and cause adverse effects on the environmental system (Pereira et al. 2010). In this case, a disruption on agroecosystem by pesticide results in an impact on beneficial predators and could lead to secondary pest outbreak and pest resistance (Guedes et al. 2016). Studies of pesticide are important for the creation of sustainable management systems that allow for the mitigation of adverse effects (Radcliffe and Hutchison 2009).

Despite the significance of the evaluation of the environmental impact of pesticides in the community of ants, results focusing on these objectives are not available for wheat cultures. Thus, the present work aimed at investigating the impacts caused by the application of the insecticides thiamethoxam and chlorpyriphos and the herbicide metsulfuron-methyl on ant communities in wheat cultures.

2. Material and Methods

Experimental Conditions

This study was carried out in Coimbra, Minas Gerais State, Brazil (20°51’24”S, 42°48’10”W and an altitude of 648 m). The soil type of the area resembles the Paleudult of the American Classification (Argissolo by the Brazilian Soil Classification System), which is nutrient poor with a moderate depth and low water permeability (Soil Survey Staff 2014; Santos et al. 2018). The wheat cultivar was the IAC 289, and the crop cycle took 129 days.

Plot Design and Treatments

The experiment was carried out in a factorial scheme of 2 (chlorpyriphos and thiamethoxam) × 2 (with and without herbicide) + 2 (Control (No weed control) and herbicide (weed control with herbicide)) in a randomized block design with four repetitions. The plots were 20 × 20 m and were separated from each other by a 5-meter-wide lateral border.

The pesticides used were the insecticides chlorpyriphos 480 EC [144 g of active ingredient ai. ha^{-1}] and thiamethoxam 250 WG (18.75 g of active ingredient ai. ha^{-1}) and the herbicide metsulfuron-methyl 600 WG (4 g of active ingredient ai. ha^{-1}). These pesticides were selected because they were the main products used in wheat cultures in Brazil (Mapa 2020).

The pesticides were applied with the use of a pressurized costal sprayer with CO_2, maintained at a constant pressure and calibrated to apply 500 $L.ha^{-1}$ of suspension for the insecticides and 200 $L.ha^{-1}$ for the herbicide. The application of the herbicide occurred 30 days after the emergence of the plants, and the application of the insecticides occurred when the plants were at the stage after the beginning of the heading stage. The number of planting days was 42.

Data Collection

The application of the herbicide occurred 30 days after the emergence of the plants (08/07/2008) and the application of the insecticides occurred when the plants were at the stage between the end of the heading stage and the beginning of the grain maturation (09/24/2008).

The community of edafic ants was evaluated on 09/22, 09/25, 10/02, 10/08, 10/22 and 11/05/2008. These dates occurred two days before and 1, 8, 14, 28 and 42 days after the application of the insecticides. The communities of ants were evaluated on the surface and inside the soil. To evaluate the ants on the surface of the soil, a pitfall trap was installed (15 cm of diameter × 10 cm of height) in the center of each experimental plot for 48 hours. For the evaluation inside the soil, a sample of the soil was removed with a depth of 30 cm and a diameter of 10 cm in each experimental plot (Sabu et al. 2011; Sonoda et al. 2011).

These samples were taken to the laboratory and were submitted for 48 hours to a Berleze funnel there, in accordance with Sabu et al. (2011). The ants collected were separated into morphospecies using a stereomicroscope. The morphospecies collected were sent to a taxonomist for identification.

Statistical Analysis

The ants collected were separated into guilds according to their food habit (Fowler 1996). The relative abundance (average and standard error) of the morphospecies and the richness of species in each guild were calculated for each treatment. The diversity of ants by treatments and date was determined by the Shannon–Weaver index (Shannon and Weaver 1949).

For the evaluation of the pesticide impact on relative abundance, the morphospecies with an occurrence frequency higher than 10% were selected. This procedure was adopted because the species of higher Relative abundance are primarily responsible for the high variance (Badji et al. 2007).

Principal Response Curves (PRC) using the program R statistical software system, package Vegan, was performed (Oksanen et al. 2019). The taxa weight of each morphospecies was calculated. These indexes indicate the contribution of each morphospecies in the PRC diagram. The morphospecies that presented taxon weights that were between −0.5 and 0.5 did not affect the PRC. The morphospecies with taxa weights that were higher than 0.5 presented positive correlations with the PRC, while the morphospecies with taxa weights that were lower than −0.5 presented negative correlations with the PRC. Therefore, graphics were made of the frequency of the morphospecies with taxon weights higher than 0.5 and lower than −0.5.

3. Results

Six families, 11 tribes, 15 genera, and 19 morphospecies belonging to the guilds of fungivorous, omnivorous, and predaceous ants were observed on wheat culture soil. All these morphospecies were observed on the surface of the soil, while only 16 of them were observed berlese funnels. Three, five, and eleven of these morphospecies belong to the guilds of fungivorous, predaceous, and omnivorous ants, respectively (Table 1).

The omnivorous ants presented more relative abundance and frequency, both on the surface and berlese funnels. The ants of each guild with a higher frequency of capture on the pitfall traps were as follows: the fungivorous *Mycocepurus* sp. (Hymenoptera: Formicidae), the omnivorous *Pheidole* sp.2 (Hymenoptera: Formicidae), and the predaceous *Gnamptogenys striatula* (Mayr 1884) (Hymenoptera: Formicidae) and *Strumigenys* sp. (Hymenoptera: Formicidae). Berlese funnels, the ants of each guild with a higher frequency of capture were as follows: *Cyphomyrmex* sp. (fungivorous) (Hymenoptera: Formicidae), *Pheidole* sp.2 (omnivorous) (Hymenoptera: Formicidae), and *Pachycondyla striata* (Smith 1858) (predaceous) (Hymenoptera: Formicidae). Eight and thirteen of the morphospecies observed on the surface and inside the soil presented a frequency of occurrence above 10%. These were selected for the investigation on the impact of the treatments on ant relative abundance and frequency, using the PRC technique (Table 1).

The insecticides chlorpyriphos and thiamethoxam reduced the richness of ants of all the guilds on the surface and inside the soil. The herbicide metsulfuron-methyl reduced the richness of predaceous ants on the surface of the soil and of fungivorous and omnivorous ants inside the soil (Table 2).

A reduction in the diversity of ants was observed over time owing to the application of the insecticides chlorpyriphos and thiamethoxam both on the surface and inside the soil. The application of the herbicide metsulfuron-methyl also reduced ant diversity on the surface and inside the soil. However, the impact of this herbicide on ant diversity was lower than that caused by the insecticides. The joint applications of insecticides and herbicide affected the richness of ants in a similar manner to the isolated application of the insecticides (Figure 1).

The analysis of the canonical variables indicated significant differences between the treatments in the communities of ants both on the surface and inside the soil. Only one canonical axis was significant, and it explained 51.75% and 55.29% of the variances in the communities of ants on the surface and inside the soil, respectively. In the community of ants of the soil surface, 40% of this variance was caused by the treatments and 18.8% by time. In the community of ants inside the soil, 37.8% of this variance was due to the treatments and 14.8% was due to time.

Table 1. Abundance and frequency of edafic ants sampled by pitfall traps and Berlese funnels according to the treatments in wheat field.

Taxa	Number of ants/sample (mean ± standard error)						Frequency (%)
	Control	Metsulfuron-methyl Mm)	Thiamethoxam		Chlorpyriphos		
			Without Mm	With Mm	Without Mm	With Mm l	
PITFALL TRAPS	Fungivorous						
Atta sexdens rubropilosa	0.72 ± 0.17	0.10 ± 0.05	0.00 ± 0.00	0.10 ± 0.05	0.10 ± 0.05	0.10 ± 0.05	16.67
Cyphomyrmex sp.	3.03 ± 0.72	0.09 ± 0.04	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	22.62
Mycocepurus sp.	0.59 ± 0.27	0.08 ± 0.04	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	13.10
	Omnivorous						
Brachymyrmex sp.	0.81 ± 0.21	0.20 ± 0.14	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	11.90
Camponotus rengeri	0.83 ± 0.15	0.75 ± 0.23	0.60 ± 0.20	0.50 ± 0.11	0.50 ± 0.20	0.20 ± 0.07	40.48
Linepithema sp.	0.75 ± 0.31	0.49 ± 0.17	0.00 ± 0.00	0.10 ± 0.05	0.10 ± 0.05	0.00 ± 0.00	17.86
Megalomyrmex	12.75 ± 3.41	1.11 ± 0.27	0.90 ± 0.26	0.60 ± 0.20	0.35 ± 0.11	0.00 ± 0.00	45.24
Pheidole sp.1	0.09 ± 0.05	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.38
Pheidole sp.2	7.16 ± 3.23	2.32 ± 0.44	0.40 ± 0.11	0.60 ± 0.11	0.30 ± 0.08	0.00 ± 0.00	48.81
Pheidole sp.3	1.54 ± 0.28	0.11 ± 0.07	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	19.05
Solenopsis sp.1	0.38 ± 0.14	0.21 ± 0.11	0.00 ± 0.00	0.00 ± 0.00	0.20 ± 0.10	0.10 ± 0.05	13.10
Solenopsis sp.2	3.07 ± 0.72	0.96 ± 0.32	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	26.19
Solenopsis sp.3	1.07 ± 0.28	0.05 ± 0.04	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	14.29
Wasmannia sp.	0.14 ± 0.05	0.11 ± 0.07	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	7.14
	Predaceous						
Gnamptogenys striatula	0.04 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.19
Hypoponera sp.	0.04 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.19
Neivamyrmex sp.	0.10 ± 0.05	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	3.57
Pachycondyla striata	0.43 ± 0.13	0.54 ± 0.17	0.50 ± 0.11	0.10 ± 0.05	0.35 ± 0.11	0.10 ± 0.05	27.38
Strumigenys sp.	0.32 ± 0.15	0.05 ± 0.04	0.00 ± 0.00	0.00 ± 0.00	0.10 ± 0.05	0.00 ± 0.00	7.14
BERLESE FUNNELS	Fungivorous						
Atta sexdens rubropilosa	0.00 ± 0.00	0.07 ± 0.04	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.47
Cyphomyrmex sp.	0.20 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.33 ± 0.16	0.25 ± 0.11	0.00 ± 0.00	9.88
Mycocepurus sp.	0.85 ± 0.22	0.00 ± 0.00	0.10 ± 0.05	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	13.58
	Omnivorous						
Brachymyrmex sp.	0.57 ± 0.33	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	3.70

Camponotus rengeri	0.76 ± 0.30	0.22 ± 0.08	0.00 ± 0.00	0.10 ± 0.05	0.09 ± 0.05	0.00 ± 0.00	14.81
Linepithema sp.	0.16 ± 0.09	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.47
Megalomyrmex	2.44 ± 0.57	1.17 ± 0.53	0.20 ± 0.10	0.00 ± 0.00	0.09 ± 0.05	0.10 ± 0.05	29.63
Pheidole sp.2	4.07 ± 1.65	1.35 ± 0.19	0.30 ± 0.11	0.50 ± 0.11	0.36 ± 0.11	0.50 ± 0.11	56.79
Pheidole sp.3	0.04 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.23
Solenopsis sp.1	0.25 ± 0.08	0.60 ± 0.25	0.11 ± 0.053	0.00 ± 0.00	0.00 ± 0.00	0.10 ± 0.05	14.81
Solenopsis sp.2	0.49 ± 0.24	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.25 ± 0.11	0.00 ± 0.00	7.41
Solenopsis sp.3	0.97 ± 0.27	0.13 ± 0.07	0.33 ± 0.16	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	14.81
			Predaceous				
Gnamptogenys striatula	1.05 ± 0.39	0.07 ± 0.04	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	12.35
Pachycondyla striata	0.24 ± 0.13	0.20 ± 0.11	0.11 ± 0.05	0.22 ± 0.11	0.38 ± 0.12	0.00 ± 0.00	9.98
Strumigenys sp.	0.68 ± 0.30	0.20 ± 0.08	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	12.35

Table 2. Richness and main response curve statistics for the guilds of edafic ants sampled by pitfall traps and Berlese funnels according to the treatments in wheat field.

Guilds	Number of morphospecies/treatment						
	Control	Metsulfuron-methyl (Mm)	Thiamethoxam		Chlorpyriphos		Total
			Without Mm	With Mm	Without Mm	With Mm	
			PITFALL TRAPS				
Fungivorous	3	3	1	1	1	0	3
Omnivorous	11	10	4	2	4	2	11
Predaceous	5	2	1	1	1	1	5
Total	19	14	6	4	6	3	19
			BERLESE FUNNELS				
Fungivorous	2	1	1	1	1	0	3
Omnivorous	9	5	4	2	4	2	10
Predaceous	3	3	1	1	1	0	3
Total	14	9	6	4	6	2	16

Megalomyrmex sp. (Hymenoptera: Formicidae), *Pheidole* sp.2 (Hymenoptera: Formicidae), *Cyphomyrmex* sp. (Hymenoptera: Formicidae), *Solenopsis* sp.2 (Hymenoptera: Formicidae), *Solenopsis* sp.3 (Hymenoptera: Formicidae), *Atta sexdens rubropilosa* (Forel 1908) (Hymenoptera: Formicidae), and *Pheidole* sp.3 (Hymenoptera: Formicidae) were the morphospecies on the soil surface that presented taxon weight higher than 0.5. All these morphospecies reduced their occurrence frequencies owing to the application of the insecticides chlorpyriphos and thiamethoxam. The application of the herbicide metsulfuron-methyl only reduced the frequencies of occurrence of *Megalomyrmex* sp., *Cyphomyrmex* sp., *Solenopsis* sp.2, A. *sexdens rubropilosa* and *Pheidole* sp.3. The joint applications of the insecticides with the herbicide affected the abundance of the ants on the pitfall traps, similar to the isolated application of the insecticides (Figures 2a and 3).

Pheidole sp.2, *Megalomyrmex* sp., *Strumigenys* sp., *Solenopsis* sp.2, *Mycocepurus* sp., and *Camponotus renggeri* (Emery, 1894) (Hymenoptera: Formicidae) were the morphospecies inside the soil that presented taxon weights higher than 0.5. All these morphospecies reduced their occurrence frequencies with the application of the insecticides chlorpyriphos and thiamethoxam. The application of the herbicide metsulfuron-methyl only reduced the frequencies of occurrence of *Pheidole* sp.2, *Solenopsis* sp.3, and *C. rengeri*. The joint applications of the insecticides and herbicide caused an effect that was similar to that of the isolated application of the insecticides on the abundance of the ants inside the soil (Figures 2b and 4).

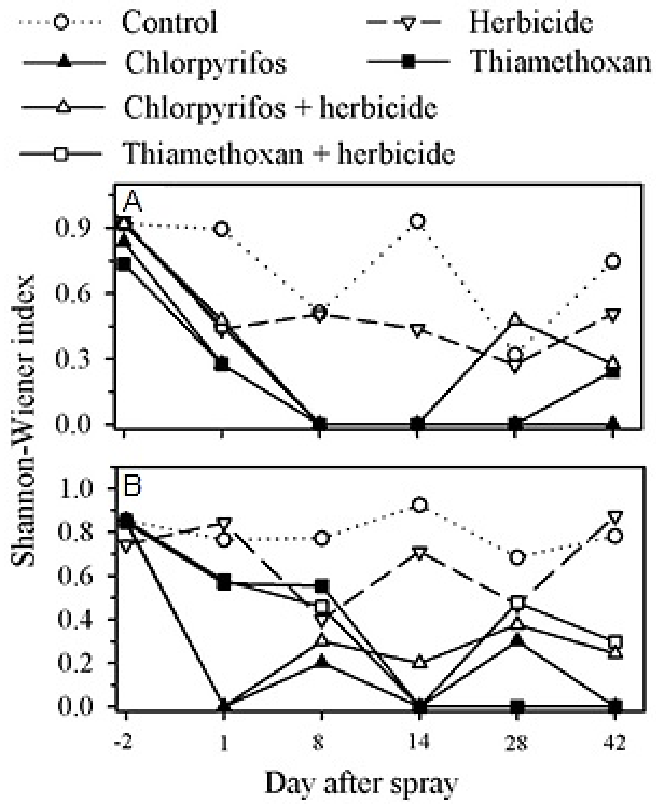

Figure 1. A - Shannon–Weaver diversity index of the community of ants sampled by pitfall traps and B - Berlese funnels in wheat field according to the application of insecticides and herbicide.

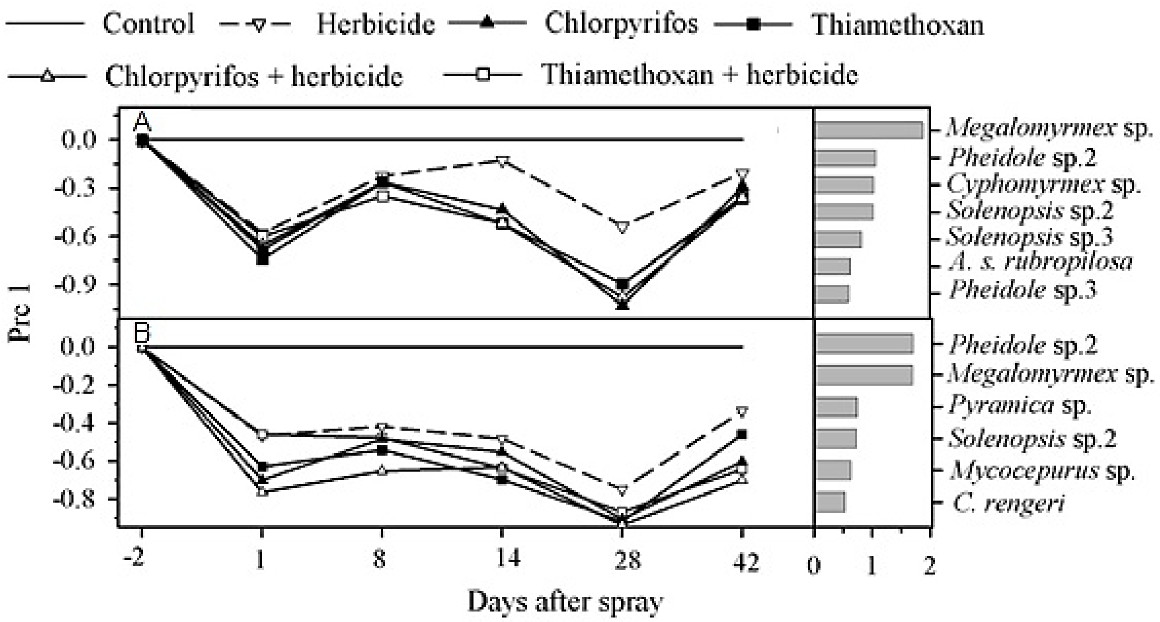

Figure 2. A - Canonical coefficients and taxon weights of the community of ants sampled by pitfall traps and B - Berlese funnels in wheat field, according to the application of insecticides and herbicide.

4. Discussion

The number of morphospecies found in the wheat culture was lower than that observed in polycultures (28 genera) and in native forests (41 genera) (Höfer et al. 2001; Leal et al. 2012). Possibly, it occurs because monocultures are simplified ecosystems, which offer less shelter and food to the species living in them (Stephens et al. 2016).

The higher abundance, frequency, and diversity of omnivorous ants compared to the fungivorous and predaceous ants occurred because the omnivorous species present a higher competitive capacity since they explore a wider variety of resources (Battirola et al. 2005). Among the omnivorous ants, the *Pheidole* sp.2 inside the soil and *Megalomyrmex* on the soil surface were the morphospecies with the highest relative abundance and frequency. This fact occurs because of their great capacity of omnivorous ants to adapt to environments with higher disturbance, such as agroecosystems (Fowler 1996). The fact that the genus *Pheidole* has a wide distribution in the neotropical region also contributes to this (Sarnat et al. 2015).

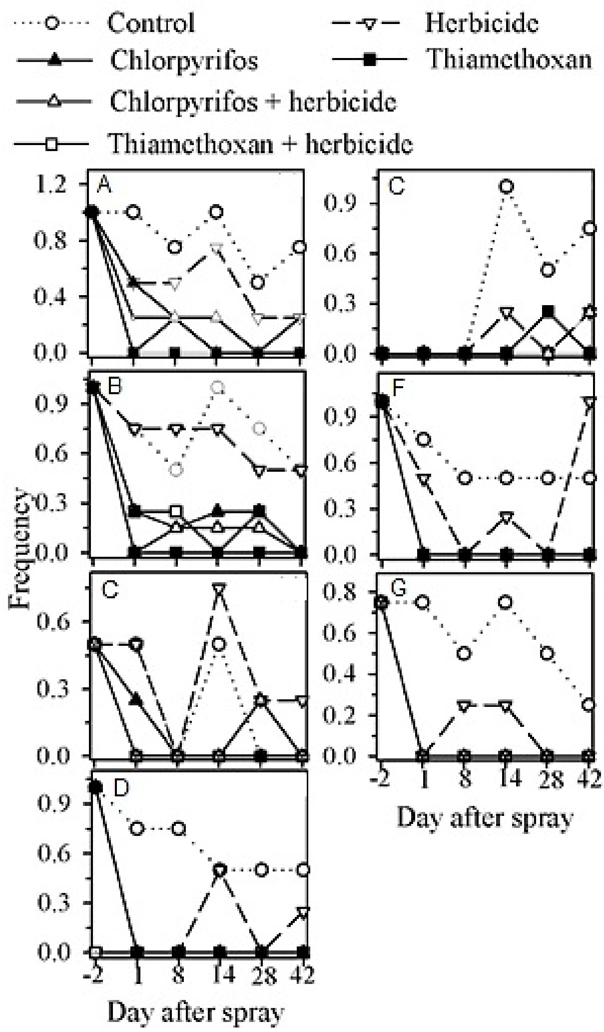

Figure 3. Frequency of the A - omnivorous *Megalomyrmex* sp., B - *Pheidole* sp.2, C - *Pheidole* sp.3, F - *Solenopsis* sp.2, and G - *Solenopsis* sp.3 as well as of the E - fungivorous *Atta sexdens rubropilosa* and D - *Cyphomyrmex* sp. sampled by pitfall traps in wheat field according to the application of insecticides and herbicide.

Cyphomyrmex sp. was the most abundant ant among the fungivorous species observed on the soil surface. Inside the soil, the most abundant fungivorous ant was *Mycocepurus* sp. This may be because the species of these genera adapt to many environments and find abundant resources in the wheat cultures (Kellner et al. 2013; Canal-Daza and Andrade-Castañeda 2019).

Gnamptogenys striatula and *Strumigenys* sp. were the most abundant predaceous ants inside the soil, while *Pachycondyla striata* was the most abundant predaceous ant on the soil surface. It is a generalist species that preys termites, arthropod larvae and earthworms (Heller et al. 2008; Monzó et al. 2013; De La Mora et al. 2015; Santos et al. 2017). These groups are important predators and generalists that any disturbance can compromise the biological balance of the soil.

The effect of the metsulfuron-methyl on the richness and diversity of ants must not be due to its toxicity to these insects but to its impact on weeds, since weeds may provide shelter and food to ants (Pereira et al. 2005). This herbicide presents low toxicity to organisms that do not synthesize these amino acids, such as insects and mammals (Costa and Rizzardi 2014). The herbicide metsulfuron-methyl belongs to the group of the sulfonylureas, inhibiting the enzyme acetolactate synthase, which is involved in the biosynthesis of essential amino acids of the ramified chain, such as leucine, isoleucine, and valine in plants and microorganisms (Costa and Rizzardi 2014). Therefore, the application of this herbicide must be carried out rationally to reduce the impact of herbicides on the weeds that contribute to the preservation of ants, which are important predators and take part in the organic matter cycle in the agroecosystems. Pesticides in tropical environments have less effects due to high temperatures and rainfall and solar radiation that accelerate degradation reactions.

The impact of chlorpyriphos and thiamethoxam on the richness, diversity, and relative abundance of ants were observed. Chlorpyriphos is a broad-spectrum organophosphate insecticide that acts on insects by contact, ingestion, and fumigation, and thiamethoxam is a neonicotinoid insecticide that acts on the nicotinic acetylcholine receptors in the nervous system (Tomizawa and Casida 2004). Despite its efficiency in the control of insect-pests, studies have demonstrated its impact on non-target insects, such as predaceous ants (Pereira et al. 2005; Badji et al. 2007; Pereira et al., 2010; Barros et al. 2015; Lefkaditis et al. 2017). Though the resilience to agents of perturbation is not totally understood, nine morphospecies don´t exhibited impact of the pesticides. This fact demonstrates that the impact of the pesticides is low than expected. These effects impact the workers of the ants, but they cannot extinguish the anthill because it does not kill the queen.

The impact of chlorpyriphos and thiamethoxam on ant populations on the surface and inside the soil was favored in great part by the fact that much of the application solution reaches the soil. The reasons for this are the high volume of the product, which is sprayed, and the architecture of wheat plants (Llorens et al. 2010). Since wheat plant leaves present a vertical position, much of the pesticide is not intercepted by their canopy and reaches the soil. To minimize this impact, the volume should be reduced, or the applications should be performed at hours when ant foraging is low.

In conclusion, pesticides impact the relative abundance, richness, and diversity of ant communities. In this case, the mixture of insecticides and herbicide had a similar impact to that of isolated applications of insecticides. However, the effect of herbicide was lower than those insecticides.

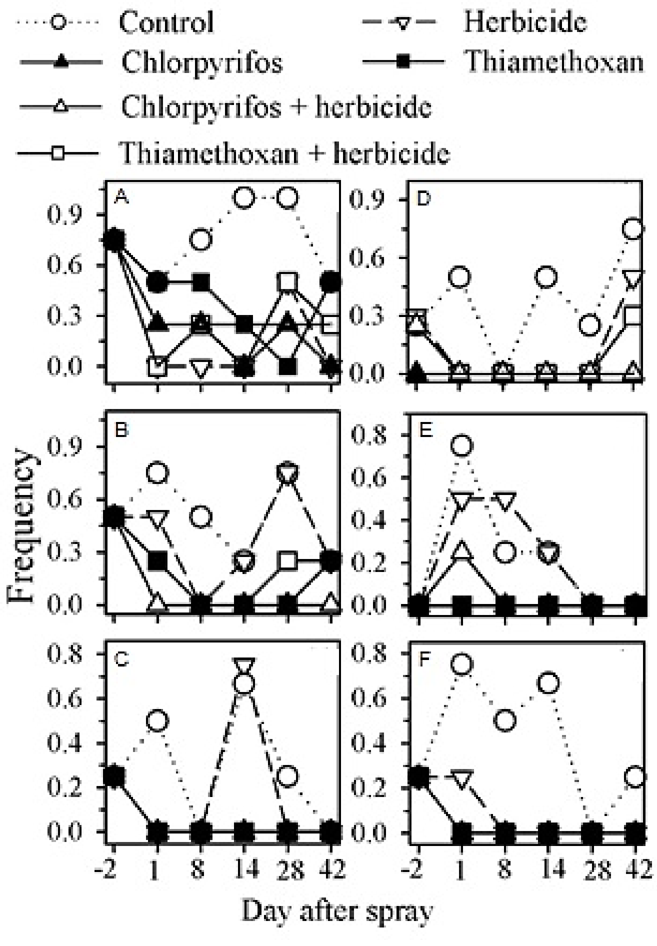

Figure 4. Frequency of the omnivorous A - *Pheidole* sp.2, B - *Megalomyrmex* sp., and D - *Solenopsis* sp.2 as well as of the E - mycophage *Mycocepurus* sp. and the C - predaceous *Camponotus rengeri* and F - *Strumigenys* sp. sampled by Berlese funnel in wheat field according to the application of insecticides and herbicide.

5. Conclusions

In our study are observed 6 families, 11 tribes, 15 genera, and 19 morphospecies belonging to the guilds of fungivorous, omnivorous, and predaceous ants observed on wheat culture soil. Three, five, and eleven of these morphospecies belong to the guilds of fungivorous, predaceous, and omnivorous ants, respectively.

The omnivorous ants present more relative abundance and frequency, both on the surface and berlese funnels. The ants of each guild with a higher frequency of capture on the pitfall traps are the fungivorous *Mycocepurus* sp., the omnivorous *Pheidole* sp.2, and the predaceous *Gnamptogenys* and *Strumigenys* sp.. Berlese funnels, the ants of each guild with a higher frequency of capture are *Cyphomyrmex* sp. (fungivorous), *Pheidole* sp.2 (omnivorous), and *Pachycondyla striata* (predaceous).

The insecticides chlorpyriphos and thiamethoxam reduce the richness of ants of all the guilds on the surface and inside the soil. The herbicide metsulfuron-methyl reduces the richness of predaceous ants on the surface of the soil and of fungivorous and omnivorous ants inside the soil.

A reduction in the diversity of ants is observed over time owing to the application of the insecticides chlorpyriphos and thiamethoxam both on the surface and inside the soil. The application of the herbicide metsulfuron-methyl also reduces ant diversity on the surface and inside the soil. However, the impact of this herbicide on ant diversity is lower than that caused by the insecticides. The joint applications of insecticides and herbicides affect the richness of ants in a similar manner to the isolated application of the insecticides.

Megalomyrmex sp., *Pheidole* sp.2, *Cyphomyrmex* sp., *Solenopsis* sp.2, *Solenopsis* sp.3, *Atta sexdens rubropilosa*, and *Pheidole* sp.3 were the morphospecies on the soil surface that present taxon weight higher than 0.5. All these morphospecies reduce their occurrence frequencies owing to the application of the insecticides chlorpyriphos and thiamethoxam. The application of the herbicide metsulfuron-methyl only reduces the frequencies of occurrence of *Megalomyrmex* sp., *Cyphomyrmex* sp., *Solenopsis* sp.2, *A. sexdens rubropilosa* and *Pheidole* sp.3. The joint applications of the insecticides with the herbicide affect the abundance of the ants on the pitfall traps, similar to the isolated application of the insecticides.

Pheidole sp.2, *Megalomyrmex* sp., *Strumigenys* sp., *Solenopsis* sp.2, *Mycocepurus* sp., and *Camponotus renggeri* are the morphospecies inside the soil that presented taxon weights higher than 0.5. All these morphospecies reduce their occurrence frequencies with the application of the insecticides chlorpyriphos and thiamethoxam. The application of the herbicide metsulfuron-methyl only reduces the frequencies of occurrence of *Pheidole* sp.2, *Solenopsis* sp.3, and *C. rengeri*. The joint applications of the insecticides and herbicides cause an effect that was similar to that of the isolated application of the insecticides on the abundance of the ants inside the soil.

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