DIVERSITY OF EPIEDAPHIC FAUNA IN LONG-TERM INTEGRATED CROP-LIVESTOCK SYSTEMS IN THE CERRADO REGION

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ABSTRACT
The epi-edaphic macrofauna are important for soil functioning and their populations are sensitive to soil management. In this study, the effect of integrated and continuous cropping systems on the edaphic macrofauna was evaluated in a long-term experiment at Embrapa Cerrados in Planaltina-DF, Brazil. Sampling took place in the wet and dry seasons of 2019, using pitfall traps in nine treatments with two replicates, including crop-livestock integration with or without cover crops and with minimum cultivation or no-tillage; continuous pasture of pure grass or intercropped with legumes; continuous tillage with and without cover crops; and a fragment of native Cerrado vegetation. A strong seasonality was observed, with 56 indicator macrofauna morphospecies in the rainy season and 38 in the dry season. Integrated systems in the cropping phase had greater dominance of some groups of fauna, such as ants, beetles and moth catterpillars, leading to lower Shannon diversity values. No-tillage, integrated systems with cover-crops and the native Cerrado had the highest morpho-species richness, showing potential as repositories of local epi-edaphic macroinvertebrate biodiversity.
Key words: Soil invertebrates; Macrofauna; Agropastoral systems

INTRODUCTION

Agricultural and animal production are important global environmental forces, affecting climate change, soil degradation, loss of biodiversity and water pollution (GERBER et al., 2013). Considering current restrictions for the expansion of agricultural frontiers, agricultural systems must be intensified and increased (SAATH; FACHINELLO, 2018) in an environmentally friendly manner, in order to reduce degradation and loss of productive capacity. Fortunately, many farmers have been replacing conventional systems with integrated agricultural production systems in Brazil (EMBRAPA, 2018), taking advantage of synergies between various components of the agroecosystem, instead of relying on higher input levels (PETERSON et al., 2019).

Integrated agricultural systems can be divided into four categories: agropastoral or integrated crop-livestock systems (ICL); silvopastoral or integrated livestock-forestry systems (ILF); silviagricultural or integrated crop-forestry systems (ICF); and agrosilvopastoral or integrated crop-livestock-forestry systems (ICLF) (BALBINO et al., 2011).

The use of pastures in rotation with cropping systems is an important option for soil improvement, with a change in plant species and root systems in the soil, as because the pasture grasses increase soil protection, carbon contents, and aeration, water infiltration capacity (BALBINO et al., 2011) and soil fauna populations (MARCHÃO et al., 2009). Hence, there is increasing interest in the adoption of agropastoral practices in no-tillage systems (NT), due to the benefits of forage straw on soil quality (MENDONÇA et al., 2013; GARCIA et al., 2014). However, in the Cerrado region, the occurrence of a prolonged dry season may be an important limiting factor to be considered (MOTA et al., 2020).

Soil and litter can offer different niches for edaphic fauna, with different microclimate conditions and space-time resources, consequently stimulating the development of a diverse community of fauna and microorganisms (CORREIA, 2002). Soil fauna are sensitive to changes in soil and climatic factors, especially those that determine the availability of food resources, changing these communities (LAVELLE et al., 1994). Their communities are also frequently related to various soil chemical (e.g., pH, organic matter, Ca, Mg, N and P contents) and physical (e.g., bulk density, porosity, aggregation) soil properties, so these animals can and are frequently used as bioindicators of disturbance and of soil quality (PAOLETTI, 1999).

Therefore, the present study aimed to evaluate the effect of integrated and non-integrated production systems on the epi-edaphic macrofauna populations, in a long-term trial in the Brazilian Cerrado.

MATERIAL AND METHODS

The study area is an experiment established in 1991 in Embrapa Cerrados, in Planaltina-DF, (15º36'S and 47º42'W), in the Central Plateau of Brazil, at 1100 m altitude. The climate of the region according to Köppen is tropical rainy (Aw) with a defined dry season in the Fall and Winter (May-September) and a rainy season in Spring and Summer (October-April). Sampling was conducted in February (0 mm rainfall) and August (149 mm rainfall) of 2019. The soil of the area was characterized as an OXISOL (Santos et al., 2018) with a clay texture (572 g kg^{-1}). The experiment had two replicates (random block design) and nine treatments as briefly described in Table 1.

Table 1. Description of the treatments evaluated at the long-term experiment in Planaltina-DF.

<table>
<tr><th>Treatment</th><th>Initials</th><th>Land use systems evaluated</th><th>Variations</th></tr>
<tr><td rowspan="4">Crop-livestock integration (ICL)</td><td>CL-L1</td><td rowspan="2">Crop rotation/intercropped pasture; pasture phase</td><td rowspan="2">1 = Minimum cultivation (sowing in stover/spontaneous vegetation) 2 = No-tillage (predominance of forage as cover crops)</td></tr>
<tr><td>CL-L2</td></tr>
<tr><td>CL-C1</td><td rowspan="2">Pasture/crop rotation; crop phase</td><td rowspan="2">1 = Minimum cultivation (sowing in stover/spontaneous vegetation) 2 = No-tillage (predominance of forage as cover crops)</td></tr>
<tr><td>CL-C2</td></tr>
<tr><td rowspan="2">Annual continuous crop</td><td>MC</td><td>Continuous minimum tillage</td><td rowspan="2">MC = Minimum cultivation (sowing in stover/spontaneous vegetation) NT = No-tillage (predominance of forage as cover crops)</td></tr>
<tr><td>NT</td><td>No tillage</td></tr>
<tr><td rowspan="2">Pasture</td><td>P1</td><td rowspan="2">Continuous pasture</td><td>1 = Pure grass</td></tr>
<tr><td>P2</td><td>2 = Intercropped with legumes</td></tr>
<tr><td>Cerrado</td><td>CE</td><td>Cerrado sensu stricto (Control)</td><td></td></tr>
</table>

The epiedaphic macrofauna were sampled using pitfall traps with 400 mL of 70% alcohol and two drops of neutral detergent in a plastic cup (10 cm height x 9 cm diameter) placed in holes in the soil. A plastic plate was placed over the cup to protect from rainfall (AQUINO et al., 2006). The traps were arranged in two parallel transects 60 m long, separated 5 m from each other and at least 20 m from the plot border. A total of 144 traps were installed, with 8 traps per block per treatment and season. Duplicate traps from each transect point were combined to create a single sample, resulting in four samples per plot and eight samples per treatment per sampling date. Traps remained in the field for 72 hours, and, after removal, were taken to the laboratory, where the material was washed in running water to remove impurities using a 0.35 mm sieve, and placed in preservative solution (80% ethanol).

All individuals were counted under a binocular stereoscopic microscope and separated at the level of Order and Family and then at the morphospecies level within each main taxon, based on the external morphological features using appropriate identification keys (RAFAEL et al., 2012; BACCARO et al., 2015). All morphospecies were photographed and the frequency data were submitted to PAST (statistical software) where the richness and other ecological indices (Shannon, Simpson, Pielou) were calculated (HAMMER et al., 2001). Means were tested for significant differences between treatments with a Tukey test ($p < 0.05$) in R (R CORE TEAM, 2019).

RESULTS AND DISCUSSIONS

The total number of invertebrates captured with the fall traps was 14,392 individuals (ind.) in a total of 22 different taxa, with 9,140 being collected in the rainy season (February) and 5,252 ind. in the dry season (August) (Table 2). In the rainy season, the greatest number of individuals was found in the ICL system CL-C1 in the crop phase (1,344 ind.), followed by annual crop in NT (1,276 ind.) and the native Cerrado (1,233 ind.). The lowest abundance was in the annual crop under MC (742 ind.) and in the ICL system CL-L1 in the pasture phase (737 ind.). In the dry season, highest abundance was found in ICL in the CL-C2 in the crop phase (1,319 ind.), followed by the crop area under no-tillage with NT cover plants (889 ind.). The lowest abundances were in the Cerrado, in the continuous pasture P2 and the area of ICL in the pasture phase CL-L2, with 311, 282 and 245 ind., respectively.

In total, 368 morpho-species (morphosp.) of epiedaphic fauna were found in all the traps. In the rainy season richness ranged from 58 morphosp. in the ICL system CL-C1 up to more than 90 in the Cerrado (95 morphosp.) and the NT system with cover crops (93 morphosp.). In the dry season richness decreased considerably, being highest in ICL system CL-C2 and in the annual NT crop, with 54 and 52 morphosp., respectively. The systems with the lowest richness were the ICL systems in the pasture phase (CL-L1 and CL-L2), with 31 and 29 morphosp., respectively. Regardless of season, the taxa with the greatest abundance and highest morphosp. richness were Formicidae (ants), Araneae (spiders) and Coleoptera (beetles).

In the rainy season, the annual crop under NT had the highest diversity (Shannon) with significantly higher value than the annual crop under MC, and in the ICL systems CL-C2 and CL-C1. In the dry season, the integrated system CL-C2 in the crop phase had the lowest Shannon diversity, being lower than in all systems except CL-L2, MC and P2. Diversity measured using the other indices (Simpson, Pielou dominance and equitability) in the rainy season, was significantly lower in the ICL system CL-C1 in the crop phase than all the other systems, while in the dry season, it the ICL system CL-C2 in the crop phase that had the lowest diversity.

Climate seasonality, typical of the Cerrado region, is an important determinant of the activity of soil fauna that are affected by the higher soil temperature and lower humidity (Lima et al., 2020). In the present experiment, macroinvertebrate abundance in the traps was 1.7 times greater in the rainy than the dry season. Coleoptera larva were observed only in the rainy season, probably because their larval stage occurs only in the period with adequate soil moisture (Assis Júnior, 2000). Macrofauna diversity was also affected by climate, with higher average richness and Shannon index in all systems in the rainy than dry season.

The NT cropping system with cover plants proved to be an important niche for the maintenance of a larger and more diverse community of epiedaphic macrofauna in both seasons. The lack of soil preparation and presence of straw protects the soil and provides food and shelter for these invertebrates. The ICL systems in the crop phase (such as CL-C1 and CL-C2), had lower diversity indices than the pasture systems (P1 and P2) and similar to the annual crops in MC, despite the relatively high morphospecies richness in the CL-C2 system in both seasons. This lower diversity is probably due to higher dominance of some morphospecies (Martins et al., 2018; Rousseau et al., 2014).

Tabela 2. Total number of individuals and morphospecies, and various diversity indices in areas with ICL systems (CL-C1, CL-C2, CL-L1, CL-L2), native Cerrado vegetation (CE), annual crops (MC, NT), and pastures (P1, P2) in February and August of 2019.

Treatment	Nº total ind.	Nº total morphosp.	Shannon		Simpson		Dominance		Equitability	
		Rainy season - February 2019								
Cerrado	1,233	95	2.48	ABC	0.85	A	0.15	B	0.74	A
ICL										
CL-C1	1,344	58	1.24	D	0.50	B	0.50	A	0.46	B
CL-C2	1.133	80	1.94	C	0.73	A	0.27	B	0.63	AB
CL-L1	737	72	2.11	ABC	0.78	A	0.22	B	0.71	A
CL-L2	1,055	70	2.09	ABC	0.77	A	0.23	B	0.67	A
Tillage										
MC	742	69	1.99	BC	0.75	A	0.25	B	0.68	A
NT	1,276	93	2.53	A	0.85	A	0.15	B	0.74	A
Pasture										
P1	828	89	2.09	ABC	0.77	A	0.23	B	0.69	A
P2	792	82	2.31	AB	0.82	A	0.18	B	0.75	A
		Dry season - August 2019								
Cerrado	311	41	1.84	A	0.76	A	0.24	B	0.78	A
ICL										
CL-C1	706	45	1.93	A	0.76	A	0.24	B	0.72	A
CL-C2	1,319	54	1.06	B	0.39	B	0.61	A	0.39	B
CL-L1	560	31	1.75	A	0.75	A	0.25	B	0.74	A
CL-L2	245	29	1.52	AB	0.67	A	0.33	B	0.76	A
Tillage										
CM	617	37	1.51	AB	0.63	A	0.37	B	0.66	A
NT	889	52	1.74	A	0.67	A	0.33	B	0.63	A
Pasture										
P1	323	35	1.65	A	0.80	A	0.30	B	0.73	A
P2	282	34	1.53	AB	0.65	A	0.35	B	0.71	A
Total	14,392	368	2.26		0.77		0.23		0.66	

* capital letters mean significant differences between treatments in the same sampling period (Tukey p <0.05).

CONCLUSIONS

Abundance and diversity of epiedaphic macrofauna are strongly influenced by season, decreasing dramatically in the dry season. In the integrated systems in the cropping phase, greater dominance of some groups of fauna such as ants, spiders and moth caterpillars lead to lower diversity (Shannon). The no-tillage system, the integrated system in the crop phase with cover crops, and the native Cerrado vegetation maintain the greatest richness of epiedaphic macrofauna, highlighting their potential as local macroinvertebrate biodiversity repositories.

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