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Soil macrofauna associated with cover crops in an Oxisol from the southwest of Piauí state, Brazil

Macrofauna edáfica associada a plantas de cobertura em um Latossolo Amarelo do sudoeste do estado do Piauí, Brasil

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ABSTRACT: The soil macrofauna is fundamental for the maintenance of soil quality. The aim of this study was to characterize the soil macrofauna under different species of cover crops, including monoculture or intercropping associated to two types of soil management in the southwest region of Piauí state. The study was carried out in an Oxisol (*Latossolo Amarelo*, according to Brazilian Soil Classification System) in the municipality of Bom Jesus, Piauí, distributed in 30 m^2 plots. Testing and evaluation of the soil macrofauna were conducted in a 9 × 2 strip factorial design, with combinations between cover crops/consortia and soil management (with or without tillage), with four replications. Soil monoliths (0.25 × 0.25 m) were randomly sampled in each plot for macrofauna at 0–0.1, 0.1–0.2, and 0.2–0.3 m depth, including surface litter. After identification and counting of soil organims, the relative density of each taxon in each depth was determined. The total abundance of soil macrofauna quantified under cover crops in the conventional and no-tillage system was 2,408 ind. m^{-2}, distributed in 6 classes, 16 orders, and 31 families. The results of multivariate analysis show that grass species in sole cropping systems and no-tillage presents higher macrofauna density, in particular the taxonomic group *Isoptera*. No-tillage also provided higher richness of families, where *Coleoptera* adult were the second more abundant group in no-tillage and *Hemiptera* in conventional tillage.

KEYWORDS: no-tillage; soil quality; soil invertebrates; bioindicators.

RESUMO: Os organismos da macrofauna edáfica são fundamentais para a manutenção da qualidade do solo. O objetivo deste trabalho foi caracterizar a macrofauna edáfica sob diferentes espécies de plantas de cobertura, incluindo monocultura ou cultivo consorciado associados a dois tipos de manejo do solo no sudoeste do Piauí. O estudo foi realizado em Latossolo Amarelo (Sistema Brasileiro de Classificação de Solos) no município de Bom Jesus, Piauí, distribuídos em parcelas de 30 m^2. O experimento e avaliação da macrofauna edáfica foram conduzidos em um ensaio fatorial em faixas 9 × 2, com combinações entre culturas /consórcios de cobertura e manejo do solo (com ou sem preparo), com quatro repetições. Os monólitos de solo (0,25 × 0,25 m) foram retirados aleatoriamente de cada parcela, para contagem da macrofauna, nas camadas de 0–0,1, 0,1–0,2, e 0,2–0,3 m de profundidade, inclusive liteira de superfície. Após a identificação e contagem dos organismos, foi determinada a densidade relativa de cada táxon em cada profundidade. A abundância total da macrofauna edáfica quantificada no experimento foi de 2.408 ind.m^{-2}, distribuídos em 6 classes, 16 ordens e 31 famílias. Os resultados da análise multivariada revelaram que espécies de gramíneas em sistemas de cultivo solteiro e plantio direto favoreceram maior densidade da macrofauna, em especial do grupo taxonômico *Isoptera*. A ausência de preparo também proporcionou maior riqueza de famílias, destacando-se o grupo taxonômico *Coleoptera* adulto em plantio direto e *Hemiptera* em plantio convencional.

PALAVRAS-CHAVE: sistema plantio direto; qualidade do solo; invertebrados edáficos; bioindicadores.

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INTRODUCTION

The southwest region of the Piauí state is one of the main agricultural frontiers of the Cerrado biome and is part of the region known as Matopiba, in reference to the States of Maranhão, Tocantins, Piauí, and Bahia, where Cerrado areas are rapidly being converted to grain production. In these regions, the replacement of native vegetation by grain production systems promotes changes in the structure of soil macroinvertebrate communities in relation to the natural condition of Cerrado (SANTOS et al., 2016). No-tillage (NT) has been recommended as an alternative to minimize the impacts of converting native areas to intensive agriculture because it is more conservationist and there is minimal soil exposure. Similarly, the use of cover crops as green manures in NT, when associated with crop rotation, favors nutrient recycling, soil aggregation, water storage, and organic matter maintenance compared to annual monocultures (CARVALHO et al., 2014; DIEL et al., 2014). Cover crops can also stimulate the activity of the soil fauna, allowing greater balance in the functioning of the soil (BRÉVAULT et al., 2007).

The establishment of soil fauna communities and their modifications depend on factors such as temperature, precipitation, humidity, soil management, among others. Maintaining vegetation cover on the soil surface prevents loss of soil macrofauna diversity and favors the activity of ecosystem engineer organisms (JONES et al., 1994) including earthworms, ants, and termites (MARCHÃO et al., 2009; BARTZ et al., 2013). Thus, because soil invertebrates also contribute to nutrient cycling, they can be effectively influenced by both the quantity and quality of plant material into the soil (TRIPATHI et al., 2010). Additionally, because of the several roles for soil functioning and sensitivity to management, especially in the soil-litter interface, soil macrofauna has been used as an indicator of soil quality (PEREIRA et al., 2017).

Despite the importance of soil macrofauna for the balance and functioning of ecosystems, few studies have been conducted in agricultural frontier regions, especially in the Cerrado biome and its ecotones. In this region, some studies mention that land use negatively affects these organisms. SANTOS et al. (2017) evaluated different land uses in Cerrado/Caatinga transition areas and found soil fauna is negatively impacted by different crops when compared to the natural condition. In a study on agroforestry systems, LIMA et al. (2010) observed that soil management systems affect the structure of dominant taxa of soil macrofauna. NUNES et al. (2012) and LUZ et al. (2013), evaluating the epigeal fauna in the litter of pasture areas, concluded that the burning of Andropogon grass pastures resulted in a reduction in the abundance and diversity of the soil fauna. These studies also concluded that the extensive cattle raising without adequate rest periods associated to incorrect grazing management decreases the diversity of soil organisms. In sugarcane crop, ABREU et al. (2014) concluded that conventional tillage soil significantly reduced soil fauna when compared to straw maintenance management. Finally, SANTOS et al. (2016), in grain production systems in Cerrado located in the state of Piauí, found that no-tillage provides greater diversity of soil macrofauna when compared to conventional tillage, with number of families similar to native vegetation.

The role of cover crop species on soil biodiversity, however, is still unknown for Matopiba region. Thus, the aim of this study was to characterize the soil macrofauna under different species of cover crops, including monoculture or intercropping crop associated to two types of soil management in the southwest region of state of Piauí.

MATERIAL AND METHODS

The study was carried out in an experimental area of Professora Cinobelina Elvas *campus* (CPCE), Universidade Federal do Piauí (UFPI), in the municipality of Bom Jesus, in the state of Piauí (09°04'59" S, 49°19'36" W, and altitude 290 m). The climate of the region (Fig. 1) is classified as warm and semi-humid Aw, according to Köppen classification, with annual average temperature of 30°C and precipitation of 1,024 mm (INMET, 2017). The soil of the experimental area was characterized as Oxisol or *Latossolo Amarelo Distrófico típico* according to Brazilian Soil Classification System (SANTOS et al., 2013), with sandy loam texture and kaolinitic mineralogy. The soil of the area was characterized by particle size distribution of soil in the 0−0.3 m layer and mineralogical attributes of the diagnostic horizon equivalent to layer 1.00−1.50 m , presenting, respectively, the following results: 210 g kg^{-1} of clay, 45 g kg^{-1} of silt, and 745 g.kg^{-1} of sand, with 9.30% de SiO_2; 2.10% of Fe_2O_3; 18.50% of Al_2O_3; 0.55% of TiO_2; 8.80 the molecular ratio Al_2O_3/Fe_2O_3; 0.85 the molecular ratio Ki; and 0.80 the molecular ratio Kr. Mineralogical analyzes were performed by sulfuric attack extraction (EMBRAPA, 1997). For the extraction of iron, aluminum, titanium, and silica in the Air Dry Fine Earth (TFSA) residue after dissolution with 1:1 sulfuric acid, heated to boiling under reflux with subsequent cooling, dilution and filtration. The silica was determined in the residue, and iron, aluminum, and titanium in the filtrate. The molecular ratios Ki and Kr were determined using the formulas: Ki=1.70 (SiO_2/Al_2O_3) and Kr=1.70 SiO_2/(Al_2O_3+Fe_2O_3 0.6375). Soft undulating relief and native vegetation of cerrado/tropical deciduous caatinga transition also characterize the area.

The experiment was installed in December 2011 to evaluate the abundance of individuals and the number of families of the soil macrofauna under the following species/consortia of cover crops under conventional tillage (CT) and no-tillage (NT): brachiaria monoculture (Ub) (*Urochloa brizantha*),

millet (Pg) (*Pennisetum glaucum*), sorghum (Sb) (*Sorghum bicolor*), brachiaria intercropped with rice (Ub+A) (*Urochloa brizantha+Oryza sativa*), brachiaria intercropped with corn (Ub+M) (*Urochloa brizantha+Zea mays*), Stylosanthes campo grande (Sty) (*Stylosanthes capitata+S. macrocephala*), Guandu bean (Cc) (*Cajanus cajan*), crotalaria juncea (Cj) (*Crotalaria juncea*), and crotalaria paulínea intercropping with corn (Cp+M) (*Crotalaria paulinea+Zea mays*).

The experimental design was factorial with nine cover crop combinations (species/consortia) and two management systems arranged in strips (conventional tillage and no-tillage) with four replications (plots). Each plot resulting from the combination of cover crop species/consortia and tillage system comprised an area of 30 m², five meters wide by six meters long.

Before the stablishment of the experiment, 2.0 Mg ha^{-1} of dolomitic lime was applied and immediately incorporated with a plow harrow. Application of 0.45 Mg ha^{-1} simple superphosphate and 0.11 Mg ha^{-1} KCl was performed simultaneously to the planting of crops/intercrops at every initial period of the rainy season (October/November) in all treatments. In the plots with grasses monoculture or grass/grass intercropping, 0.10 Mg ha^{-1} N (Urea) was applied 28 days after planting. Since 2011 to soil sampling in 2014, the same soil fertilization was applied for the same crops/intercrops used.

Each year, the cover crops material was evenly spread over the soil surface using a mower coupled to a tractor (mulcher) after the end of the crop season. In CT, the soil was ploughed with a harrow while in NT the spontaneous vegetation was desiccated with herbicide.

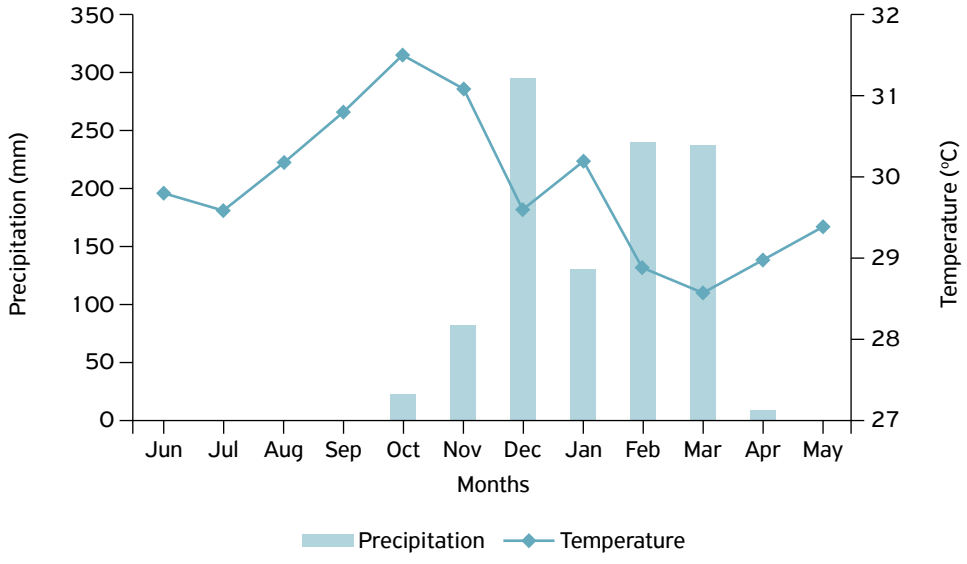
After three successive cultivation cycles (2011/2012, 2012/2013, and 2013/2014 harvests), soil monoliths were collected in each plot during the second half of May of 2014, to characterize the soil macrofauna according to recommendations of the Tropical Soil Biology and Fertility Program (TSBF) described in ANDERSON; INGRAM (1993). Soil monoliths of 0.25 × 0.25 m stratified in 0–0.1, 0.1–0.2, and 0.2–0.3 m layers, including litter, were collected at two points within each plot defined after randomly casting a 0.25 × 0.25 m sampler metal frame. Soil samples were also collected for chemical characterization as recommended by DONAGEMA et al. (2011), which results are shown in Table 1.

The screening of the invertebrates from the soil monoliths were performed with the naked eyes immediately after the sampling, at outdoor condition adjacent to the experimental area. The invertebrates were stored in pots with 70% diluted alcohol, and then sent to the entomology laboratory of the Federal University of Piauí, in Bom Jesus, state of Piauí, Brazil, for counting and taxonomic identification of organisms to family level.

Absolute abundance results for each family in each area were expressed as relative density (number of individuals per m²) in the 0–0.3 m layer, including litter. The relative density for each crop and management systems was calculated from the average of each area. The vertical distribution in each area was calculated from the averages of the four repetitions in each layer.

For statistical analysis, relative density data (number of individuals per square meter) were grouped into the following taxonomic groups: *Arachnida,* adult *Coleoptera*, larvae *Coleoptera*, *Diptera*, *Hemiptera*, *Hymenoptera,* and *Isoptera*. The other taxa identified, but which had relative density less than 5% of the total, were grouped as "others".

Due to the nature of the data we opted for a principal component analysis (PCA), which was performed in the matrix composed by 72 rows (nine cover crops/consortia, two types



Source: INMET (2017).

Figure 1. Rainfall and monthly average temperature between June 2013 and May 2014, Bom Jesus, Piauí state, Brazil.

of soil management and four replications) and nine columns (groups) to identify, among the variables corresponding to the macrofauna groups, which contributed the most weight in the linear combination of the first two main components.

With the aid of the ADE-4 program to interpret the results, in addition to the circle of correlations between the eigenvectors of the variables, treatment ordering diagrams were constructed categorizing them to evaluate the effect of the cover crops grouped as grass in consortium with legumes (G+Leg); monoculture legumes (Leg); intercropping grasses (Gc) and monoculture grasses (Gs), and by soil management systems (conventional tillage and no-tillage). Discriminant analysis based on Mahalanobis dissimilarity or distance was used to compare the mathematical distances between the samples in the ordering diagram. This type of analysis uses a permutation test that calculates the total interclass inertia for each random distribution of individuals and, by association with a statistical probability, allows maximizing the discriminating power of the analysis (THIOULOUSE et al., 1997).

RESULTS AND DISCUSSION

The total population density of soil macrofauna quantified in the experimental area was 2,408 ind.m^{-2}, distributed in 6 classes, 16 orders, and 31 families (Table 1). The number found in this study was higher than in other studies conducted in the state of Piauí, such as SANTOS et al. (2016) in conventional tillage and no-tillage in the Cerrado of Piauí, and ABREU et al. (2014) in sugarcane under conventional tillage every five years in the Caatinga biome. From another perspective, SANTOS et al. (2017), evaluating the soil macrofauna in different land use systems in the same region, found higher values of abundance.

From the total of identified and quantified individuals distributed in the six classes, there was a wide predominance of the Insecta class with 25 families, representing a total of 98.01% of the total relative density of the edaphic macrofauna (Table 2). The other classes represented in descending order of relative density were Arachnida (1.20%), Chilopoda (0.43%), and finally, Diplopoda, Gastropoda, and Malacostraca, both representing 0.12% each. The predominance of the Insecta class in Cerrado soils and its ecotones is quite common, a fact verified by SANTOS et al. (2016), and SANTOS et al. (2017). According to RUPPERT et al. (2005), the Insecta class is considered the largest known group of living beings, being over 70% of existing animal species, performing ecological functions in soil and environment, such as biological control, soil structure, and fertility, among others.

Among all orders, *Isoptera* group represented 73.87% of the soil macrofauna quantified in the PC. SANTOS et al. (2016) and SANTOS et al. (2017), respectively also observed this predominance of Isoptera in conventional tillage soil. Among *Isoptera* groups, the family *Termitidae* was the most abundant in all systems. The organisms of this taxon are fundamental to the functioning of highly weathered soils as they make resources available to other soil organisms through their biogenic structures created in the soil (LAVELLE, 1996; OLIVEIRA et al., 2012).

In areas with no-tillage (NT), we highlight the treatments with the presence either of grasses, monoculture or

Table 1. Average values of soil chemical attributes in all cover crops and tillage systems in the 0-0.3 m deep layer, after three years of cover crop cultivation at Bom Jesus municipality, southwest Piauí, Brazil.

Cover crops/ tillage systems	Soil chemical attributes										
	pH	K	Ca	Mg	H+Al^{3+}	Al^{3+}	CTC	CO	MO	V	m
	$CaCl_2$	----------Cmol$_c$ dm^{-3}----------						------g Kg^{-1}----		--------%--------	
Sb	4.63	0.17	1.39	0.43	2.33	0.26	4.31	4.13	7.12	46.41	12.85
Ub	4.64	0.14	1.30	0.62	2.35	0.20	4.41	3.10	5.35	46.82	10.25
Ub+M	4.49	0.15	1.15	0.68	2.60	0.25	4.58	3.06	5.28	43.97	12.78
Ub+A	4.68	0.19	1.58	0.64	2.90	0.28	5.30	2.67	4.61	44.88	11.59
Pg	4.50	0.21	1.23	0.45	2.25	0.27	4.14	2.29	3.95	46.34	13.24
Cc	4.62	0.17	1.40	0.50	2.08	0.26	4.15	1.88	3.24	49.62	12.31
Sty	4.61	0.17	1.57	0.52	2.36	0.30	4.62	2.17	3.74	49.24	12.39
Cj	4.80	0.21	1.58	0.40	2.34	0.24	4.53	3.71	6.40	48.15	10.79
Cp+M	4.84	0.22	1.69	0.59	2.48	0.20	4.97	3.11	5.35	49.09	9.56
CT	4.56	0.19	1.37	0.54	2.49	0.25	4.59	2.80	4.84	45.79	11.98
NT	4.73	0.17	1.49	0.53	2.33	0.25	4.52	3.00	5.17	48.55	11.52

Sb: *Sorghum bicolor*; Ub: *Urochloa brizantha*; Ub+M: *Urochloa brizantha*+Corn; Ub+A: *Urochloa brizantha*+Rice; Pg: *Pennisetum glaucun*; Cc: *Cajanus cajan*; Sty: *Stylosanthes capitata+S. macrocephala*; Cj: *Crotalaria juncea*; Cp+M: *Crotalaria paulinea*+Corn; CT: conventional tillage; NT: no-tillage.

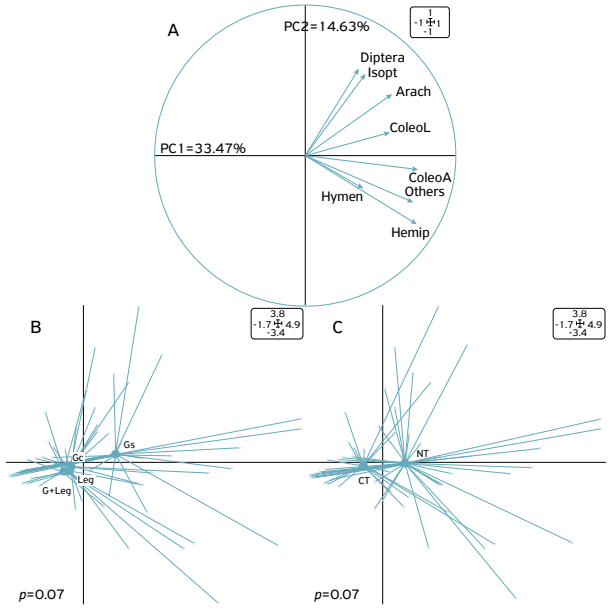
Table 2. Relative density (ind. m^{-2}) and richness of soil macrofauna families associated with different cover crops/intercropping under conventional tillage and no-tillage in southwest Piauí.

Cla	Ord	Families	Ground cover plants associated with conventional tillage and no-tillage(2)																	
			Sb		Ub		Ub+M		Ub+A		Pg		Cc		Sty		Cj		Cp+M	
			CT	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT
Ara[1]	Ara[2]	*Theridiidae*	3±1.7	2±2.1	1±0.7	3±1.7	1±0.9	1±0.7	1±0.7	1±0.9	3±1.7	2±1.5	1±0.7	2±1.5	1±0.9	2±1.5	0	1±0.7	1±0.9	1±0.9
Ara[1]	Sco	*Scorpionidae*	0	0	0	1±0.9	0	0	0	0	0	0	0	1±0.7	0	0	0	0	0	0
Ins	Bla	*Blaberidae*	0	0	0	1±0.7	0	0	0	0	0	0	0		0	0	0	0	0	0
Ins	CAd	*Carabidae*	2±2.1	6±4.5	2±1.5	5±3.7	7±4.0	13±15.4	6±7.0	2±1.1	8±7.6	2±1.1	1±0.7	2±1.5	4±2.3	4±1.7	1±0.7	4±2.3	1±0.7	2±2.1
Ins	CAd	*Scarabaidae*	1±0.9	0	0	1±0.7	0	1±0.7	0	0	0	0	1±0.7	1±0.7	0	0	0	0	1±0.7	1±0.7
Ins	CAd	*Staphylinidae*	4±3.5	8±5.8	1±0.7	13±11.9	2±1.9	1±0.7	0	0	4±4.9	1±0.7	0	1±0.7	3±2.8	3±1.9	9±8.7	1±0.7	0	3±3.5
Ins	CAd	*Languridae*	0	1±1.4	0	1±0.9	0	0	0	1±0.9	0	0	1±0.7	2±2.1	1±0.7	1±0.7	2±2.8	1±0.9	0	0
Ins	CAd	*Tenebrionidae*	0	1±0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins	CLa	*Elateridae*	3±1.9	7±4.2	2±1.1	2±1.2	3±2.8	2±1.9	3±1.3	8±5.7	3±1.7	9±8.4	0	7±4.9	1±0.7	3±1.3	1±0.9	2±1.6	1±0.9	3±1.7
Ins	CLa	*Curculionidae*	1±1.4	0	1±0.7	2±1.6	0	1±0.7	0	0	1±0.71	1±0.9	0	1±0.7	0	0	1±0.7	0	0	1±1.4
Ins	CLa	*Melolonthidae*	0	1±0.7	1±0.7	1±0.9	0	1±0.7	0	0	0	3±2.5	0	0	0	1±1.4	0	1±0.7	0	1±0.7
Ins	CLa	*Chrysomelidae*	1±0.7	3±2.0	5±0.9	3±2.2	3±3.0	3±2.2	2±2.1	0	1±0.9	1±0.7	0	1±0.9	1±0.9	1±0.7	1±0.9	1±0.9	0	1±0.7
Ins	Dip[2]	*Asilidae*	1±0.9	0	0	2±1.6	1±0.7	1±0.7	0	0	1±0.71	1±0.7	0	1±1.4	0	1±0.7	0	2±2.1	0	0
Ins	Hem	*Cicadidae*	0	1±1.4	2±1.5	1±0.7	0	2±1.5	0	0	2±1.5	0	0	0	1±0.7	1±1.4	0	0	0	0
Ins	Hem	*Pentatomidae*	2±2.1	6±4.0	2±1.5	2±1.6	0	1±0.7	1±0.7	1±1.4	0	0	0	1±0.7	1±0.7	5±2.7	1±0.9	0	0	1±0.7
Ins	Hem	*Cydinidae*	1±0.7	1±0.7	0	1±1.4	0	0	0	0	0	0	0	0	0	1±0.7	1±1.4	5±6.36	0	1±0.7
Ins	Hem	*Coreidae*	0	0	0	0	0	0	0	0	1±0.7	0	0	0	0	0	0	0	0	0
Ins	Hem	*Alydidae*	0	0	0	0	0	0	1±0.7	0	0	0	0	0	0	0	0	0	0	0
Ins	Hym	*Formicidae*	8±5.2	14±8.3	21±20.9	13±7.7	15±14.6	29±17.9	3±1.7	7±5.7	28±36.6	5±4.9	4±2.5	2±1.5	2±1.2	10±7.0	8±5.9	4±4.2	57±64.7	43±41.1
Ins	Hym	*Apidae*	0	0	0	0	0	0	1±1.7	0	0	1±0.71	0	0	0	0	0	0	0	0
Ins	Iso[1]	*Termitidae*	226±174.5	131±82.6	9±7.9	257±210.0	167±139.8	117±75.1	71±59.8	27±34.5	7±7.2	159±164.5	95±83.4	123±120.6	11±9.8	55±42.2	8±7.1	13±7.3	213±226.8	46±39.9
Ins	Iso[1]	*Rhynotermitidae*	0	2±2.1	6±6.4	3±1.9	0	0	0	1±0.71	1±0.7	0	0	0	0	0	0	0	0	0
Ins	Iso[1]	*Mastotermitidae*	0	0	0	1±0.7	0	0	0	0	0	0	0	0	0	0	0	1±1.4	0	0
Ins	Lep	*Nymphalidae*	0	2±1.5	2±1.5	1±0.7	0	1±0.7	0	1±0.7	0	1±0.9	0	0	0	0	1±0.9	2±1.5	0	0
Ins	Ort	*Grylidae*	0	1±0.9	0	0	0	1±0.7	0	0	1±1.4	1±0.7	0	0	1±0.7	0	0	0	1±0.71	1±0.7
Ins	Ort	*Acrididae*	1±0.7	0	0	0	0	1±0.9	0	0	0	0	1±0.7	0	0	0	0	0		0
Ins	Der	*Anisolabididae*	0	0	0	0	0	0	0	0	0	0	1±0.7	0	0	0	0	1±0.7	0	0
Chi	Sco	*Scolopocryptopidae*	0	1±0.7	0	2±1.5	0	1±0.9	0	0	1±0.7	0	0	0	1±0.7	2±1.1	0	2±1.5	0	0
Dip[1]	Pol	*Polidesmidae*	0	0	0	0	0	1±1.4	0	1±0.7	0	0	0	0	0	0	0	0	0	1±1.4
Gas	Pul	*Planorbidae*	0	0	0	0	1±0.7	0	0	0	0	0	0	0	0	1±0.7	0	1±1.4	0	0
Mal	Iso[2]	*Porcellionidae*	0	0	0	3±3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum of density			254±19.9	188±11.5	55±2.0	319±22.5	200±14.7	178±10.5	89±6.2	50±2.5	62±2.5	187±14.0	105±8.3	145±10.8	28±1.0	91±4.8	34±1.2	42±1.2	275±19.3	106±5.4
Nº of families			13	17	13	22	09	18	09	10	14	13	08	13	12	15	11	16	07	14

(2)Sb: *Sorghum bicolor*; Ub: *Urochloa brizantha*; Ub+M: *Urochloa brizantha*+ Corn; Ub+A: *Urochloa brizantha*+Rice; Pg: *Pennisetum glaucun;* Cc: *Cajanus cajan;* Sty: *Stylosanthes capitata+S. macrocephala;* Cj: *Crotalaria juncea;* Cp+M: *Crotalaria paulinea*+Corn. (1) Calculated from the average area per crop. Ad and La refer to the orders Coleoptera adult and Coleoptera larvae, respectively. Numbers after averages refer to standard error. Cla: Class; Ord: Orders; Ara[1]: *Arachnida*; Ins: *Insecta*; Chi: *Chilopoda*; Dip[1]: *Diplopoda*; Gas: *Gastropoda*; Mal: *Malacostraca*; Ara[2]: *Araneae*; Sco: *Scorpiones*; Bla: *Blattodea*; CAd: *Coleoptera* adult; CLa: *Coleoptera* larvae; Dip[2]: *Diptera*; Hem: *Hemiptera*; Hym: *Hymenoptera*; Iso[1]: *Isoptera*; Lep: *Lepdoptera*; Ort: *Ortoptera*; Der: *Dermaptera*; Sco: *Scolopendromorpha*; Pol: *Polydesmida*; Pul: *Pulmonata*; Iso[2]: *Isopoda*. CT: convencional tillage; NT: no-tillage.

in consortium, which provided better conditions to soil macrofauna organisms, more specifically *Isoptera* with higher densities. With exception of Pg, all other cover crop plants treatments showed higher richness in NT. The results also revealed consortiated systems tended to show less contrasting differences between NT and CT in total macrofauna density. The predominance of *Isoptera* in these areas is probably because these organisms are decomposers of lignocellulosic materials (LIMA; COSTA-LEONARDO, 2007). Termites might also contribute to the primary decomposition of materials with high carbon/nitrogen ratio resulting in prolonged partial decomposition with increased nutrient release to plants (RAPOSO et al., 2014). Similar results were observed by SANTOS et al. (2008) under no-tillage in Cerrado, which found greater richness of soil macrofauna individuals in grassy areas as ground cover plants, confirming their potential as ground cover. From another perspective, millet crop presented low relative density of groups and larger number of families.

In areas with revolving of soil (CT), the sum of relative density was 1,102 ind. m^{-2}, (data not shown) and the most abundant groups in decreasing order of relative density were: *Isoptera* (73.87%), *Hymenoptera* (13.34%), adults, and *Coleoptera* larvae (8.89%) followed by other groups, which represented only 3.90% of the total abundance. Based on the functional group classification proposed by BROWN et al. (2015), the dominant functional groups were geophages/bioturbers, considered ecosystem engineers (JONES et al., 1994). These individuals perform functions of creating biogenic structures (galleries, nests, chambers, and fecal acorns) that modify the physical properties of soils as well as the availability of resources for other organisms (MARCHÃO et al., 2009). Still regarding the engineer groups, cover crops promoted similar effects on the evaluation of these groups, but according to the principal component analysis (Fig. 2), there was a greater tendence of these groups in the NT.



Dip: *Diptera*; Iso: *Isoptera*; Ara: *Arachnida*; ColeoL: *Coleoptera* larvae; ColeoA: adult *Coleoptera*; Hym: *Hymenoptera*; Hem: *Hemiptera*. CT: conventional tillage, NT: no-tillage. G+Leg: grass in intercropping with legumes; Leg: monoculture legumes; Gc: intercropping grasses and Gs: monoculture grasses.

Figure 2. Correlation circle between soil macrofauna groups (A), and the diagram of discriminant analysis betwem agricultural systems (B) and soil management systems (C).

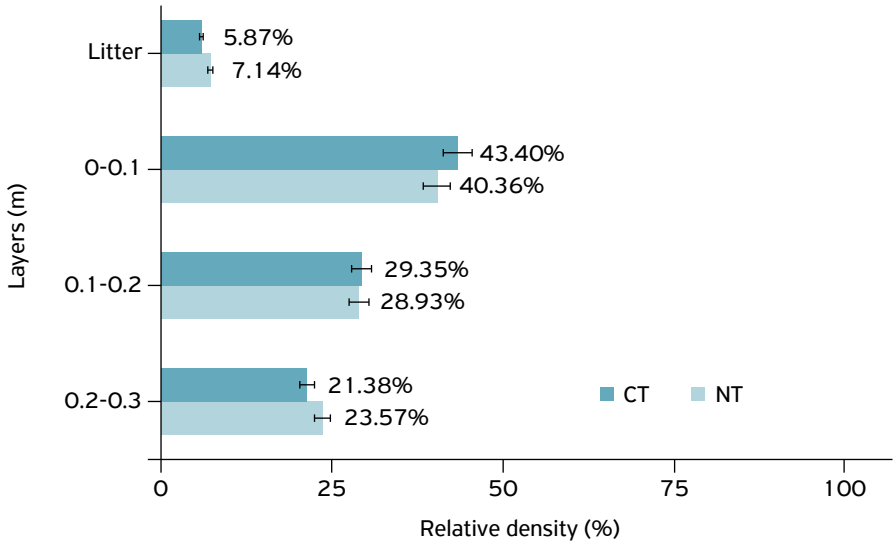
Regarding the richness of groups, the monoculture of brachiaria (Ub) was the cover plant that obtained the largest number of families (22), followed by the treatment with the same species in consortium with corn (Ub+M) with 18 families, evidencing that the Brachiaria grass is efficient in maintaining the biodiversity.

The principal component analysis (PCA), performed with the density data of the main groups of the soil macrofauna, revealed that the first two axes explained 48.10% of the total data variability, corresponding to 33.47 and 14.63% along the first and second axes respectively (Fig. 2A). Axis 1 was mainly influenced by *Coleoptera* adult group with 20.86% and *Hemiptera* with 20.33% contribution. On the other hand, axis 2 was mainly influenced by *Diptera* and *Isoptera* taxa with 27.51 and 24.54% contribution, respectively.

Although the sampling plots in the present study were small and a certain border effect was expected because of the mobility of macrofauna, the ordination diagram revealed a possible tendence of separation of monoculture grasses from other species/consortia, showing that there is a positive association between the use of grasses and no-tillage (Fig. 2B). However, it should be noted that the higher relative density of individuals in grassy areas is also related to the higher relative density of *Isoptera*, as already mentioned. High *Isoptera* densities are common in Cerrado and ecotone areas, as demonstrated by BENITO et al. (2004), CONSTANTINO (2005) and SANTOS et al. (2016).

Regarding the types of soil management, the discriminant analysis revealed that there is a separation between the areas with and without soil revolving (Fig. 2C). As already reported, treatments without revolving showed the highest relative density. Thus, it is observed that the colonization of the soil by invertebrates results not only from the association between the quantity and quality of food present in the environment (LAVELLE et al., 2014), but also from physical factors, directly related to the type of preparation employed (COLLISON et al., 2013).

Regarding the vertical distribution of macrofauna (Fig. 3), it was verified that in the cultivated areas the fauna predominates in the 0–0.1 m depth layer, with no difference in the relative distribution along the soil profile of areas with or without soil revolving. Similar results were observed in other regions, both in Cerrado (BATISTA et al., 2014; SANTOS et al., 2016) and



Bars are mean percentages with respective standard errors as a measure of data dispersion. CT: conventional tillage; NT: no-tillage.
Figure 3. Vertical distribution of the relative density of the soil macrofauna according to the soil management.

in Caatinga (NUNES et al., 2012). However, litter was the layer with the lowest relative density of soil organisms in both management systems. SANTOS et al. (2008) reported that the abundance of soil invertebrates varies with soil sampling depth for the *Formicidae*, *Lepidoptera*, adult *Coleoptera*, *Coleoptera* larvae, *Hemiptera*, *Dermaptera*, *Miriapoda*, and *Diptera* groups. Macroinvertebrates can migrate throughout the soil layers searching for food or changes in mortality and birth rates may happen, depending on the time of year, causing variation in the presence or absence of the organisms on the soil surface. Temperature is also determinant for soil macrofauna dynamics (BARETTA et al., 2003; LAVELLE et al., 2006). However, although most macrofauna taxa are responsible for litter transformation and use it as habitat and food (MOREIRA et al., 2010), the high temperatures associated with low humidity of soil most of the year in the cerrado/caatinga transition environment may have been factors that limited the presence of higher densities in litter.

CONCLUSIONS

From the total invertebrates quantified, there was a wide predominance of the Insecta class with 25 families, representing 98.01% of the edaphic macrofauna. The other classes in descending order of relative density were Arachnida (1.20%), Chilopoda (0.43%), Diplopoda, Gastropoda, and Malacostraca, both representing 0.12% each. Among all orders, *Isoptera* group (family *Termitidae)* represented more of 70% of the soil macrofauna.

Regarding the cover crop effect, *Coleoptera* adult, *Hemiptera*, *Diptera*, and *Isoptera* were the most important taxa that discriminate management systems. Grass species in sole cropping systems (*Urochloa brizantha*, *Sorghum Bicolor*, and *Pennisetum glaucun*) presents higher macrofauna density.

Comparing management systems, no-tillage provided higher density and richness of families than conventional tillage, especially *Coleoptera* adult.

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