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Soil fauna: Bioindicator of soil recovery in Brazilian savannah

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ABSTRACT

This work aimed to evaluate the employment of the soil arthropod community as a bioindicator of land reclamation on a loan area in *Mabea fistulifera* Mart. plantation under different types of fertilization, in central-western Brazil. The experimental design was a randomized complete block design within plots (type of fertilization applied in the planting line). The quarterly sampling of the organisms occurred along two years, by means of pitfall traps, in six treatments (08 traps / treatment): area without intervention (SI); planting without fertilization (D0); planting with application of mineral fertilizer (DAM); three different doses of an organic compound (industrial residue) obtained from the pulp production, 10 Mg ha^{-1} (D10), 15 Mg ha^{-1} (D15), and 20 Mg ha^{-1} (D20). Each trap was considered a sample unit. The animals were identified in high taxonomic groups (order, class, family). There was no clear pattern of the effect of the treatments on the structure (total and average richness, uniformity, diversity, total abundance) of the community. However, the principal component analysis indicated that D20 increased the abundance of a higher number of taxonomic groups / trophic guilds, in comparison to the other treatments.

Key words: degraded area; soil conditioning; *Mabea fistulifera*

Fauna edáfica: Bioindicadora de recuperação do solo em savana brasileira

RESUMO

Este trabalho objetivou avaliar o emprego da comunidade dos artrópodes edáficos como bioindicadora da recuperação de área de empréstimo de solo, em um plantio de *Mabea fistulifera* Mart. sob diferentes tipos de adubação, no centro-oeste brasileiro. O delineamento do experimento foi blocos ao acaso, em esquema de parcelas (tipo de adubação aplicada na linha de plantio). A amostragem trimestral dos organismos ocorreu em dois anos, por armadilhas de queda, em seis tratamentos (08 armadilhas/ tratamento): área sem intervenção (SI); plantio sem adubação (D0); plantio com aplicação de adubo mineral (DAM); plantio com aplicação de composto orgânico (resíduo industrial) proveniente da produção de celulose, nas doses de 10 Mg ha^{-1} (D10), 15 Mg ha^{-1} (D15) e 20 Mg ha^{-1} (D20). Cada armadilha constituiu uma unidade amostral. Os animais foram identificados em grandes grupos taxonômicos (ordem, classe, família). Não observou-se um padrão claro de efeito dos tratamentos sobre a estrutura (riquezas média e total, uniformidade, diversidade, abundância total) da comunidade estudada. No entanto, a análise de componentes principais indicou que D20 favoreceu a abundância do maior número de grupos taxonômicos / guildas tróficas, na comparação com os demais tratamentos testados.

Palavras-chave: área degradada; condicionamento do solo; *Mabea fistulifera*

Introduction

Cerrado is a wet savanna composed of a mosaic of vegetation communities that present high rates of richness and endemism of plant species (Coutinho, 2006) and that shelter several species of animals at risk of extinction (Benites & Mamede, 2008). Although this biome was originally spread over two million km^2, which corresponded to approximately 23% of the national territory, its area has now been greatly reduced, mainly by agricultural activities (Durigan et al., 2007). Despite of this, its conservation has not aroused as much interest as the Amazon Forest and the Atlantic Forest (Overbeck et al., 2015).

This situation demonstrates the need for recovery of Cerrado deforested areas. This process can be done by planting native tree species with the use of industrial waste as fertilizer. This practice contributes to minimizing the environmental liabilities of the industries producing such waste. Among them are those producing paper and cellulose, which are rich in nutrients and, in this way, may lower the cost of forest plantations (Arruda et al., 2011).

However, it is important to evaluate/monitor the effects of the application of these wastes on the recovery of degraded areas. Such practice can be made through assessments of the soil fauna community. This is based on the fact that this community, which is closely associated with the processes of decomposition and nutrient cycling, undergoes changes in its structure and composition due to changes that occur in the input of resources and microclimatic conditions, as an impact of disorders, different types of soil management (Baretta et al., 2010) and soil recovery practices (Lima et al., 2017). In this way, studies of this nature may indicate taxonomic groups that would act as potential bioindicators of the global evaluation of the soil biological quality and the ecosystem functioning.

In the present study, we tested the hypothesis that soil fertilization with the organic compound from the industrial production of cellulose is more beneficial to the soil fauna community, when compared to the conventional mineral fertilization and the absence of fertilization was tested. The objective of this work was to evaluate the soil fauna community in a plantation of *Mabea fistulifera* Mart. in central-western Brazil, in soil fertilized with different doses of the organic compound from the composting of cellulose production residues.

Material and Methods

The work area is located in the municipality of Selvíria, state of Mato Grosso do Sul, between the geographical coordinates of 51° 22' West Longitude of Greenwich and 20° 22' South Latitude. The altitude is 327 m; the relief, smooth to flat; and the original vegetation cover belongs to the Cerrado biome. The climate is humid tropical type Aw according to Köppen's classification, with a rainy season in the summer and dry season in the winter. The annual averages are of 1370 mm and 23.5 °C for total rainfall and temperature, respectively. The rainy season extends from October to March, with higher volumetric precipitation concentrated between the months of December and February. The dry season is concentrated between the months of April to September, with June, July and August representing the driest quarter, with an average monthly precipitation of 27 mm.

In 1969, the superficial soil layer was removed to the approximate depth of 8.60 m in a part of the study area that was used in the earthwork and foundation of the Ilha Solteira Hydroelectric Power Plant in the state of São Paulo. Since then, the subsoil has been exposed. The soil is classified as Red Latosol Distrophic. According to Giácomo (2013), the remaining B horizon exposes the Franco-clay-sandy textural class; 1.63 kg dm^{-3} of soil density; pH 5.6 ($CaCl_2$); 3 mg dm^{-3} of P; 1.2 mg dm^{-3} of K; 8 mmol$_c$ dm^{-3} Ca $^{2+}$; 7 mmol dm^{-3} Mg^{2+}; 14 mmol$_c$ dm^{-3} of H + Al; and 10 g dm^{-3} of organic matter.

In order to recover this area, a forest planting was carried out after the soil preparation. In this way, in December 2009, the mechanical decompression of the soil was carried out, with cross-subsoils at a depth of 0.40 m and light harrowing. In February 2010, 15 m × 72 m (n = 4) plots were established, spaced at least 3 m apart, in which the planting of *Mabea fistulifera* Mart was planted for the soil recovery purpose. This tree species, which is native to the Cerrado, provides pollen and nectar of the inflorescences, which are food resources used by different species of birds, bats and pollinating coatis (Olmos & Boulhosa, 2000).

Two hundred seedlings were planted in each plot, which were produced from seeds and donated by the Energy Company of São Paulo (CESP). The planting spacing was 3.0 m between the lines and 1.5 m inside the lines. Each plot was subdivided into six subplots (12 × 15 m), each corresponding to one of the following treatments: (SI) area without intervention, that is, without planting and without fertilization; (D0) area with planting and without fertilization; (D10) area with planting and fertilization with the residue of the industrial production of cellulose at the dose of 10 Mg ha^{-1}, which corresponded to the need of the crop; (D15) area with planting and fertilization of 15 Mg ha^{-1} of the residue; (D20) area with planting and fertilization of 20 Mg ha^{-1} of the residue; (DAM) area with planting and mineral fertilization, according to the need of the crop. Fertilizers were applied in the planting line.

The experimental design was a completely randomized block design subdivided in plots. The three central rows, which corresponded to 18 plants, were considered as useful, while the edges, as borders. The fertilization rates with the residue were calculated based on the chemical analysis of the soil and the residue. This material was supplied by the Compounding Center of the Ambitec Group, at the International Paper Unit in Mogi Guaçu, state of São Paulo. Such waste consists of a mixture of "dregs", "grits", mud-lime, ash and other residues generated throughout the industrial pulp extraction process.

Before being used, the residue underwent a composting process during 30 days. During this time, the residue was exposed in open air troughs and was periodically mechanically stirred. According to Giácomo (2013), the chemical characterization of the organic compound obtained showed the following results: 2.4 g kg^{-1} of P; 5.9 g kg^{-1} K; 86.9 g kg^{-1} Ca; 3.8 g kg^{-1} Mg; 9.5 pH ($CaCl_2$). The DAM treatment corresponded to the application per plant of 100 g of the NPK formula 8-28-16 (166,70 kg ha^{-1}) and, after 60 days, 48.8 g of urea (81.45 kg ha^{-1}) and 16.70 g of KCl (27.80 kg ha^{-1}), according to the recommendations of the

Table 1. Chemical attributes of the superficial soil (0-5 cm) in the different treatments at the *Mabea fistulifera* planting in Selvíria, MS, 12 months after the implantation of the experiment (Giácomo, 2013).

Treatment	pH	OM	P	K	Ca	Mg	H+Al	SB	CEC	V
	($CaCl_2$)	mg dm^{-3}		mmol$_c$ dm^{-3}						%
SI	5.3 c	17.3 a	7.4 c	1.5 a	11.5 c	7.7 b	16.5 a	20.7 c	37.2 c	55.3 c
D0	5.3 c	13.8 a	5.5 c	1.3 a	8.0 c	7.3 b	15.5 a	16.5 c	32.0 c	51.1 c
D10	6.7 b	15.3 a	10.7 b	1.9 a	35.0 b	10.5 a	11.0 b	47.4 b	58.4 b	79.6 b
D15	6.7 b	15.5 a	13.5 b	1.8 a	34.0 b	9.0 b	10.5 b	44.8 b	55.0 a	81.0 b
D20	7.4 a	15.8 a	32.8 a	1.5 a	100.0 a	12.5 a	8.8 b	114.0 a	122.8 a	92.4 a
DAM	5.5 c	14.5 a	4.5 c	1.5 a	9.8 c	7.8 b	15.0 a	19.0 c	34.0 c	56.0 c

Mean values followed by different lowercase letters in the column differ significantly from each other by the Scott-Knott test ($p < 0.05$). D0: planting and without fertilization; D10: planting and fertilization with residue of the industrial production of cellulose in the dose of 10 Mg ha^{-1} (crop need); D15: planting and fertilization of 15 Mg ha^{-1} of the residue; D20: planting and fertilization of 20 Mg ha^{-1} of the residue; DAM: planting and mineral fertilization (crop need). OM: organic matter; SB: sum of bases; CEC: cation exchange capacity; V: base saturation.

nursery of native seedlings of CESP. The chemical attributes of the superficial soil (layer 0.00-0.05 m) in the tested treatments were also evaluated by Giácomo (2013) (Table 1).

Soil fauna was evaluated quarterly over a period of two years (from May 2010 to February 2012), for a total of nine sampling periods. Of these, five occurred in the rainy season (rainy 1: February/2010; rainy 2: December/2010; rainy 3: February 2011; rainy 4: November 2011; rainy 5: February 2012); and four occurred in the dry season (Dry 1: May/2010, dry 2: August/2010, dry 3: May/2011, dry 4: August/2011). Two pitfall traps were installed in the central region of each subplot, totaling eight traps per treatment. Each trap was considered a sampling unit and the results were presented as averages between the collections, within each climatic season (rainy or dry).

Traps consisted of 11 cm diameter and 7.5 cm high plastic pots, which were buried in the soil with the border at the level of the soil-litter interface. The pots were then filled with approximately 400 mL of 3% acetylsalicylic acid solution to preserve the collected fauna. The traps, which were covered with a plastic dish (15 cm in diameter) supported by thin wooden stakes, to avoid dilution and overflow of the solution by rain, remained for seven consecutive days in the field (Fernandes et al., 2011).

In laboratory, the fauna was stored in plastic containers with 70% alcohol until the moment of the triage. At this stage, the organisms were transferred to Petri dishes with the aid of water-based plexiglass and 0.053 mm aperture sieve, then were quantified and identified at the level of large groups (class, order or family) under binocular magnifying glass. The structure and the composition of the soil fauna community were evaluated through total abundance (number of individuals per trap per day) and abundance of the taxonomic groups; average and total richness (number of groups); uniformity (Pielou index); and diversity (Shannon index); besides the relative contribution of the groups (%, ratio between their abundance and total community abundance).

Taxonomic groups that had a low (< 2%) relative contribution were grouped under the denomination "Others". The results were also discussed from the perspective of trophic guilds to which the taxonomic groups belong (Menezes et al., 2009; Camara et al., 2012; Pereira et al., 2013). Changes in the abundance of taxonomic groups as a response to treatments D0, D10, D15, D20 and DAM were evaluated using the V index or modification index proposed by Wardle & Parkinson (1991). For that, the SI treatment was taken as reference. This index varies from -1 to +1 and, depending on the value obtained, the treatment effect on abundance is classified in the following categories: Extreme inhibition (EI, $V < -0.67$); Moderate inhibition (MI, $-0.33 > V > -0.67$); Slight inhibition (SI, $-0.05 > V > -0.33$); Without change (WCH, $-0.05 < V < +0.05$); Slight stimulation (SS, $+0.05 < V < +0.33$); Moderate stimulation (MS, $+0.33 < V < +0.67$); Extreme stimulation (ES, $V > +0.67$) (modified by Wardle, 1995).

The values of abundance (total and groups) and mean richness were submitted to analysis of variance, and the means were compared by the non-parametric Kruskal-Wallis test ($p < 0.05$) using the BioEstat software version 5.3 (Mamirauá Institute, Belém). The multivariate analysis of principal components, processed with PAST software version 2.17c, was performed to identify possible correlations between the treatments tested and (1) chemical attributes of the soil and structural attributes of the soil fauna community (general average between climatic seasons for total abundance, richness, uniformity, diversity), and (2) abundance of taxonomic groups. Both analyses considered attributes (soil and soil fauna) that presented correlation coefficients above 0.70%, with one of the main axes: main axis 1 or main axis 2.

A generalized linear model was carried out using the STATISTICA software version 8.0 to evaluate the association between the total fauna community abundance of the soil (dependent variable) and the treatments or the climatic season (independent variables). This model is used when the dependent variable does not present a normal distribution, or when the relation between the dependent variable and the independent variable is not linear (Conceição et al., 2001).

Results and Discussion

A total of 20 taxonomic groups were found in the study area, of which 10 occurred in all treatments, in both climatic seasons (rainy and dry) (Table 2). Different taxonomic groups were excluded in DAM and D15. In both treatments, the excluded groups were Chilopoda, Mantodea, Neuroptera and Scorpionida, which represent animals that belong to the trophic guild of predators; Acari and Thysanoptera, which are saprophagous and/or predators; and Diplopoda (saprophagous). Individuals in the Hymenoptera group (predators) were not captured in DAM, while those belonging to the Isoptera group (saprophagous and/or predators) were not captured in D15.

The values of pH, P, Ca, Mg, SB, CEC and V in the soil surface layer (0.00-0.05 m) at DAM were significantly

Table 2. Relationship of presence/absence of soil fauna taxonomic groups captured in the different treatments in the *Mabea fistulifera* planting in Selvíria, MS, in the average of the rainy and dry seasons (from May 2010 to February 2012).

Groups	SI	D0	D10	D15	D20	DAM	SI	D0	D10	D15	D20	DAM
	Rainy						Dry					
Acari	-	-	X	-	-	-	-	-	X	-	-	-
Araneae	X	X	X	X	X	X	X	X	X	X	X	X
Auchenorrhyncha	X	X	X	X	X	X	X	X	X	X	X	X
Blattodea	X	X	X	X	X	X	X	X	X	X	X	X
Chilopoda	X	X	-	-	X	-	-	-	-	-	-	-
Coleoptera	X	X	X	X	X	X	X	X	X	X	X	X
Collembola	X	X	X	X	X	X	X	X	X	X	X	X
Dermaptera	X	X	X	X	X	X	X	X	X	X	X	X
Diplopoda	X	-	-	-	-	-	-	-	-	-	-	-
Diptera	X	X	X	X	X	X	X	X	X	X	X	X
Formicidae	X	X	X	X	X	X	X	X	X	X	X	X
Heteroptera	X	X	X	X	X	X	X	X	X	X	X	X
Hymenoptera	X	X	-	X	-	-	X	X	X	X	X	X
Isoptera	X	X	X	-	X	X	X	X	X	-	-	-
Lepidoptera	-	-	X	X	X	X	-	X	X	X	X	X
Mantodea	-	-	-	-	-	-	X	X	-	-	X	X
Neuroptera	-	X	-	-	-	-	X	X	-	-	X	-
Orthoptera	X	X	X	X	X	X	X	X	X	X	X	X
Scorpionida	X	X	-	-	-	-	-	X	X	-	-	-
Thysanoptera	X	X	X	X	X	-	-	-	-	-	-	-

SI: without intervention (without planting and without fertilization); D0: planting and without fertilization; D10: planting and fertilization with residue of the industrial production of cellulose in the dose of 10 Mg ha^{-1} (crop need); D15: planting and fertilization of 15 Mg ha^{-1} of the residue; D20: planting and fertilization of 20 Mg ha^{-1} of the residue; DAM: planting and mineral fertilization (crop need).

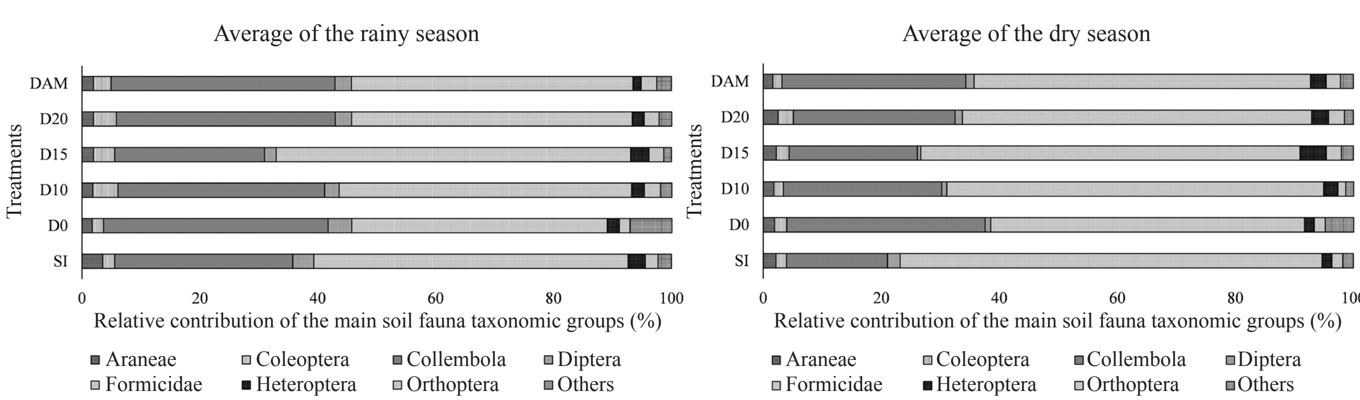
lower, while the H + Al value was significantly higher in this treatment when compared to D10, D15 and D20 (Table 1). At D15, the Mg value was significantly lower than D10 and D20. These chemical changes of the soil surface may have negatively impacted the soil fauna community, with the consequent exclusion of taxonomic groups in DAM and D15. The lower fertility of the superficial soil in DAM was probably a reflection of the greater mobility of Ca and Mg in the mineral form in the soil, with the consequent higher leaching of these cations, in relation to the fertilization with cellulosic residue.

Formicidae (saprophagous and/or predators), followed by Collembola (saprophagous and/or microphages), contributed with at least 81% of all organisms captured in the treatments studied. Araneae (predators), Coleoptera (saprophagous and/or predators), Diptera (unrecognized soil functionality), Heteroptera and Orthoptera (both groups involving herbivorous animals) also showed relevant relative contribution regardless of treatment (Figure 1).

The relative participation of Formicidae in the soil fauna community varied between 43% in D0 and 60% in D15, in the average for the rainy season, and between 53% in D0 and 71% in SI, in the average for the dry season. Collembola's contribution to the community varied between 25% of the soil fauna community in D15 and 38% in both D0 and DAM, in the average for the rainy season, and between 17% in SI and 34% in D0, in the average for the dry season.

The predominance of Formicidae and Collembola in the soil fauna community has been reported in different ecosystems, independently of the climatic season, in studies in which the animals are captured by means of pitfall traps (Alves et al., 2008; Fernandes et al., 2011; Camara et al., 2012; Lima et al., 2017). This pattern occurs due to the high abundance and diversity of these groups, in addition to the fact that such methodology favors the capture of organisms that present high activity/movement at the litter-soil interface, as in the case of ants and springtails (Sabu et al., 2011).

According to the average values of index V obtained for the rainy season, DAM presented the highest number of groups with some type of inhibition of abundance, followed by D0 (Table 3). In the dry season, the highest number of groups in



SI: without intervention (without planting and without fertilization); D0: planting and without fertilization; D10: planting and fertilization with residue of the industrial production of cellulose in the dose of 10 Mg ha^{-1} (crop need); D15: planting and fertilization of 15 Mg ha^{-1} of the residue; D20: planting and fertilization of 20 Mg ha^{-1} of the residue; DAM: planting and mineral fertilization (crop need).

Figure 1. Relative contribution (%) of the main soil fauna taxonomic groups captured in the different treatments at the *Mabea fistulifera* planting, in Selvíria, MS, in the rainy and dry seasons (May/2010 to February/2012).

Table 3. Number of soil fauna groups (% in relation to the total of groups) by category of index V in different treatments in the *Mabea fistulifera* planting, in Selvíria, MS, using as reference SI (without intervention: no planting and without fertilization), in the average of the rainy and dry seasons (period from May 2010 to February 2012).

Index category V	Treatment									
	D0	D10	D15	D20	DAM	D0	D10	D15	D20	DAM
	Rainy					Dry				
Extreme inhibition	1 (6)	4 (22)	4 (24)	4 (24)	5 (29)	0	2 (12)	3 (20)	2 (13)	2 (13)
Moderate inhibition	4 (24)	0	1 (6)	0	2 (12)	2 (13)	0	1 (7)	0	0
Slight inhibition	4 (24)	3 (17)	0	1 (6)	3 (18)	3 (19)	2 (12)	2 (13)	2 (13)	4 (27)
No change	2 (12)	2 (11)	3 (18)	1 (6)	1 (6)	3 (19)	3 (18)	1 (7)	2 (13)	1 (7)
Slight stimulation	2 (12)	5 (28)	6 (35)	6 (35)	4 (24)	4 (25)	5 (29)	5 (33)	8 (53)	5 (33)
Moderate stimulation	1 (6)	1 (6)	1 (6)	3 (18)	1 (6)	1 (6)	2 (12)	2 (13)	0	2 (13)
Extreme stimulation	3 (18)	3 (17)	2 (12)	2 (12)	1 (6)	3 (19)	3 (18)	1 (7)	1 (7)	1 (7)

D0: planting and without fertilization; D10: planting and fertilization with residue of the industrial production of cellulose in the dose of 10 Mg ha^{-1} (crop need); D15: planting and fertilization of 15 Mg ha^{-1} of the residue; D20: planting and fertilization of 20 Mg ha^{-1} of the residue; DAM: planting and mineral fertilization (crop need).

categories of inhibition occurred for DAM and D15. From the point of view of the community composition (Tables 2 and 3, Figure 1), which also considered the information about the trophic guilds of the respective taxonomic groups with greater relative contribution, it was possible to identify the effects of the treatments on the soil fauna. In this context, DAM, D15 and SI were the less favorable treatments, while D20 was the most favorable treatment for soil fauna. This fact was probably due to the better conditions of soil chemical attributes in D20, where values of P, Ca, Mg, pH, sum of bases, cation exchange capacity and base saturation were significantly higher when compared to the others treatments (Table 1). The absence of difference between the treatments studied with respect to soil organic matter, indicated that this attribute did not influence the results obtained for the soil fauna community.

In general, considering the average for both rainy and dry seasons, the community of soil fauna tended to present the lowest values of richness in DAM and D15; the lowest values of uniformity were obtained in SI and D10; and the lowest values of diversity in D10 and D15 (Table 4). On the other hand, there was a tendency of higher values of richness in D10 and SI; The highest values of uniformity in D20 and DAM; and the highest values of diversity in D20 and D0. There were no significant differences among treatments in relation to the mean values of total abundance and average community richness, for the rainy and dry seasons.

Table 4. Values of the structural attributes of the soil fauna community in the different treatments in the *Mabea fistulifera* planting, in Selvíria, MS, for the average of the rainy and dry seasons (from May 2010 to February 2012).

Structural attribute	Treatment					
	SI	D0	D10	D15	D20	DAM
	Rainy					
Total abundance	8.25 a (1.11)	9.09 a (1.48)	12.17 a (1.19)	13.83 a (1.74)	13.24 a (1.50)	8.84 a (1.15)
Average richness	10 a	10 a	10 a	10 a	10 a	9 a
Total richness	16	16	14	13	14	12
Uniformity	0.48	0.52	0.49	0.47	0.50	0.52
Diversity	1.91	2.08	1.88	1.74	1.89	1.85
	Dry					
Total abundance	9.58 a (1.81)	8.80 a (1.80)	14.21 a (1.99)	10.80 a (1.21)	11.19 a (1.16)	9.20 a (2.03)
Average richness	10 a	9 a	10 a	10 a	10 a	10 a
Total richness	14	16	15	12	13	13
Uniformity	0.39	0.45	0.39	0.46	0.47	0.46
Diversity	1.48	1.82	1.51	1.66	1.72	1.70

Mean values of total abundance in ind arm^{-1} d^{-1}, followed by the standard error in parentheses, and average richness followed by the same letter, within the same climatic season, did not differ significantly by Kruskal-Wallis non-parametric test ($p < 0.05$). SI: without intervention (without planting and without fertilization); D0: planting and without fertilization; D10: planting and fertilization with residue of the industrial production of cellulose in the dose of 10 Mg ha^{-1} (crop need); D15: planting and fertilization of 15 Mg ha^{-1} of the residue; D20: planting and fertilization of 20 Mg ha^{-1} of the residue; DAM: planting and mineral fertilization (crop need).

Based on this set of results obtained for the community structure, it was not possible to identify a clear pattern of soil fauna response regarding the treatments tested. This finding corroborated some information available in the literature about the different technics used in degraded soil areas (Kitamura et al., 2008; Vergílio et al., 2013) or fertilization of soil in forest planting (Ribeiro et al., 2008). In the same site of the present work, that is, in soil loan areas, Kitamura et al. (2008) established a monospecific planting of gonçalo (*Astronium fraxinifolium* Schott. Ex Spreng.) and the planting of this tree species in a consortium with green fertilizers, with or without soil fertilization with sewage sludge (60 t ha^{-1}). The authors did not observe significant differences regarding the total richness and density of the soil macrofauna, whne comparing these two environmental restoration treatments, an area without intervention and an area with native Cerrado vegetation

In the Cerrado areas where there was removal of the soil surface layer up to the depth of 2 m, no difference was verified among the recovery treatments (transposition of compost with/without castor bean planting (*Ricinus communis* L.) and an area of degraded pasture and another area of native vegetation, in relation to the richness of the soil fauna (Vergílio et al., 2013). However, these authors observed that the transposition of compost without the planting of castor oil caused a decrease in the uniformity and increase of the diversity.

In a monospecific planting of Australian acacia (*Acacia auriculiformis* A. Cunn.) planting in the countryside of the state of Rio de Janeiro, mineral fertilization of the soil with simple superphosphate and potassium chloride caused an increase in the richness and total density of the community present in the litter layer disposed on the soil surface (Ribeiro et al., 2014). However, these authors verified that this soil preparation decreased the values of these same attributes in the soil compartment, compared to the absence of fertilization.

It is thought that differences in the impact of various treatments on soil fauna structure can be verified by identifying taxonomic groups at lower hierarchical levels (family, gender and species). However, this refinement in identification is not easy to perform, since it requires deep taxonomic knowledge. One way of ascertaining the effect of treatments could be the complementary use of other methods of capturing the organisms of the soil fauna, since there is variation between them with respect to the efficiency of capture of different taxonomic groups (Sabu et al., 2011).

The generalized linear model analysis showed that there was a significant effect ($p < 0.05$) on the association of total community abundance with the type of treatment applied (Table 5). In spite of this, this model explained only 20% of the data variance (R2 = 0.203958), which was reinforced by the absence of significant differences between the treatments, in relation to the average of the total abundance calculated for the climatic seasons (Table 4). In addition, the generalized linear model indicated no significant effect on the association between total abundance and climatic season, and there was no significant effect of the interaction of predictor or independent variables (treatment, climatic season) on the total abundance of the soil.

According to the principal component analysis, there was a separation between the treatments studied through the relationship between the principal component 1 (axis 1) and the principal component 2 (axis 2) (Figure 2). The treatments SI, D0 and DAM were grouped in the left portion of axis 1 (negative values). In contrast, all treatments with the different doses of the organic residue (D10, D15 and D20) were grouped in the right portion of axis 1 (positive values). Therefore, it was evident that these two groups presented contrasting soil-ecological conditions for the soil fauna.

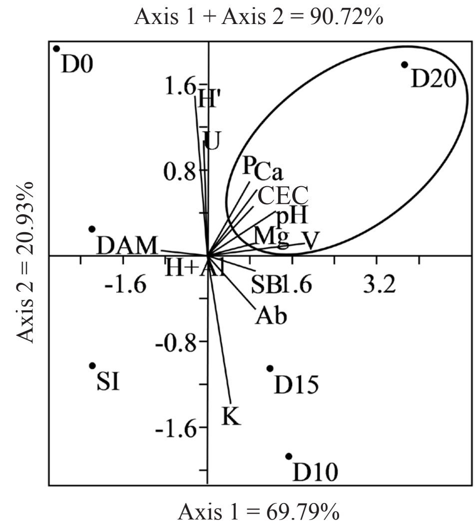
However, axis 2 indicated that there was a separation between the two groups previously mentioned (Figure 2). Thus, D0 and DAM were located in the upper portion (positive values), while SI was located in the lower portion (negative values) of this axis. Concerning fertilization treatments with the organic compound, D20 was located in the upper portion (positive values), while D10 and D15 were located in the lower portion (negative values) of axis 2. The variability of the data explained was 69.79% in axis 1 and 20.93% in axis 2, which corresponded to 90.72% of the variance.

The principal component analysis illustrated in Figure 2 corroborated the absence of a well-defined pattern regarding the impact of treatments on soil fauna structure attributes. This was due to the non-correlation of community structural attributes (total abundance, uniformity, diversity) with none of the treatments tested, since the vectors corresponding to these attributes were practically superimposed on the main axis 2 (uniformity and diversity) among different treatments, as was the case of abundance, whose vector was positioned among D10, D15 and D20.

The principal component analysis of the abundance of the taxonomic groups corroborated the separation among the treatments. SI, D0 and DAM were grouped in the left portion of the principal axis (negative values), while the treatments fertilized with organic residue (D10, D15 and D20) were grouped in the right portion of axis 1 (positive values) for the rainy and dry seasons (Figures 3A and 3B respectively). For the rainy season, the data variability explained was 50.90% in axis 1 and 35.08% in axis 2, which corresponded to 85.98% of the variance. For the dry season, the variability of the data explained was 59.09% in axis 1 and 25.70% in axis 2, totalizing 84.79% of the variance.

However, considering the principal axis 2, a general pattern of separation between treatments within these two subgroups was observed. D0 and DAM differed between themselves, since they were located in divergent portions (upper, with positive values, and lower, with negative values, respectively) (Figure 3A). For this same climatic season, there was differentiation between D20 and D15, which were located in the upper portion (positive values) and lower (negative values) of this axis, respectively.

This same pattern of treatment individualization was verified for the average of the collections made in the dry season. This occurred because D0 and DAM again were located in divergent portions of the principal axis 2 (lower, with negative values, and higher, with positive values, respectively) (Figure



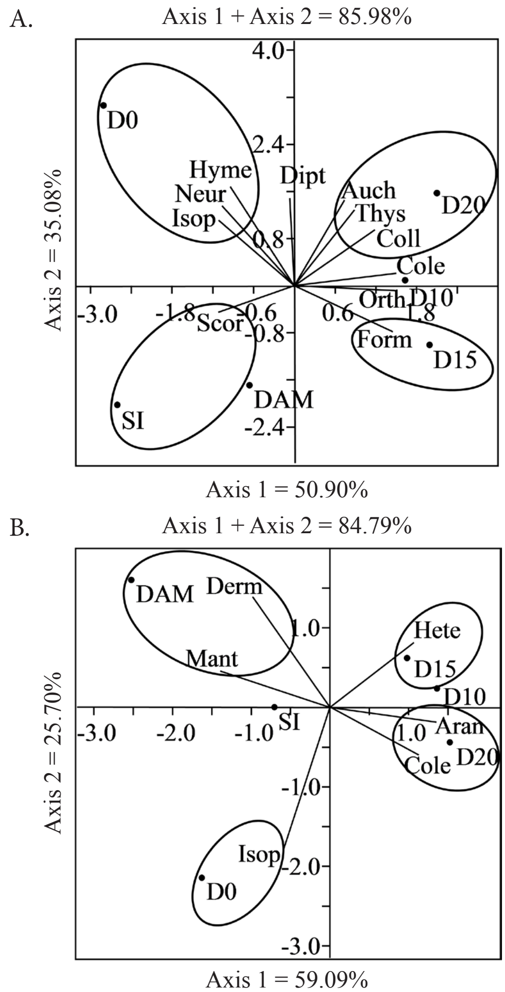
SI: without intervention (without planting and without fertilization); D0: planting and without fertilization; D10: planting and fertilization with residue of the industrial production of cellulose in the dose of 10 Mg ha^{-1} (crop need); D15: planting and fertilization of 15 Mg ha^{-1} of the residue; D20: planting and fertilization of 20 Mg ha^{-1} of the residue; DAM: planting and mineral fertilization (crop need).

Figure 2. Principal component analysis of the soil fauna community attributes (Ab: abundance, U: uniformity, H': diversity) based on the average between rainy and dry seasons (May/2010 to February/2012), soil chemical attributes (pH, P, K, Ca, Mg, H + Al, CEC: cation exchange capacity, V: base saturation) in the *Mabea fistulifera* planting, in Selvíria, MS.

Table 5. Results obtained from the analysis of the generalized linear model to evaluate the association between the total richness or abundance of the soil fauna community and the fertilization treatment and climatic season at the *Mabea fistulifera* planting in Selvíria, MS, based on the average abundance of soil fauna groups in samplings in the rainy and dry seasons (from May 2010 to February 2012).

Effect on total abundance	SQ	Degrees of freedom	QM	F	p
Intercept	545602.0	1	545602.0	596.9197	0.000000
Treatment	15835.6	5	3167.1	3.4650	0.006769
Climatic season	88.6	1	88.6	0.0970	0.756251
Treatment x Climatic season	3747.4	5	749.5	0.8200	0.538860
Error	76778.4	584	914.0		

SQ: sum of squares; QM: mean square; F: ratio between the model and its error; P: probability of significance.



Aran: Araneae; Auch: Auchenorrhyncha; Cole: Coleoptera; Coll: Collembola; Derm: Dermaptera; Dipt: Diptera; Form: Formicidae; Hete: Heteroptera; Hyme: Hymenoptera; Isop: Isoptera; Mant: Mantodea; Neur: Neuroptera; Orth: Orthoptera; Scor: Scorpionida; Thys: Thysanoptera. SI: without intervention (without planting and without fertilization); D0: planting and without fertilization; D10: planting and fertilization with residue of the industrial production of cellulose in the dose of 10 Mg ha^{-1} (crop need); D15: planting and fertilization of 15 Mg ha^{-1} of the residue; D20: planting and fertilization of 20 Mg ha^{-1} of the residue; DAM: planting and mineral fertilization (crop need).

Figure 3. Principal component analysis of the abundance of taxonomic groups and treatments of soil fertilization in the *Mabea fistulifera* planting, in Selvíria, MS, in the rainy season (A) and dry season (B)

3B). Already D20 and D15, they were located in the inferior portion (negative values) and superior (positive values) of this axis, respectively.

With respect to D10, the effect of this treatment on the abundance of the taxonomic groups was considered similar to that caused by the other doses of the organic compound, since it was positioned between D15 and D20, practically superimposed on the axis 1, for the average of the rainy season (Figure 3A). On the other hand, for the dry season, Figure 3B indicated that the effect of D10 on the abundance of the groups was closer to that caused by D15, since both were located in the upper portion of axis 2 (positive values), when it was compared to D20.

In the study period, no taxonomic group showed correlation with D10, in average for both climatic seasons. Formicidae and Heteroptera correlated with D15 (rainy and dry seasons, respectively), whereas Dermaptera and Mantodea were correlated with DAM (dry season). On the other hand, D20 was the treatment with a high correlation with the highest number of taxonomic groups, representing a wide variety of trophic guilds: Auchenorrhyncha (herbivores), Collembola (saprophagous and/or predators) and Thysanoptera (saprophagous and/or predators), averaged for the rainy season (Figure 3A), Araneae (predators) and Coleoptera (saprophagous and/or predators), on average for the dry season (Figure 3B).

In this way, D20 favored the soil fauna community, when compared with the other treatments. This fact probably occurred due to the increase in soil fertility provided by this treatment. This result was evidenced by the high correlation between the majority of soil chemical attributes (pH, P, Ca, Mg, CEC and V) and D20 (Figure 2). The same pattern favoring the abundance of taxonomic groups distributed in different trophic guilds as a reflection of the increase in soil fertility provided by fertilization, although mineral fertilization was used in this case, was previously observed in a monospecific planting of *Acacia auriculiformis*, in Conceição de Macabu, state of Rio de Janeiro (Ribeiro et al., 2014). The increase in soil fertility, caused by fertilization, is probably responsible for the increase of plant and microbial biomass (Alves et al., 2008). With this, there is a greater supply of varied food resources for different groups of soil fauna, favoring the community of these organisms and the cycling of nutrients as a whole.

Conclusions

The fertilization treatments studied did not clearly influence the indexes of richness, uniformity, diversity and total abundance of the soil fauna community.

However, the application of 20 Mg ha^{-1} favoured a greater number of taxonomic groups, distributed in a wide variety of trophic guilds, probable as a reflection of the increase in soil fertility, in comparison with the other treatments.

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