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RELATIONSHIP BETWEEN MESOFAUNA AND SOIL CHEMICAL PARAMETERS IN A BIOCHAR-MANAGED CENTRAL AMAZONIAN YELLOW OXISOL

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ABSTRACT

The present study has aimed to assess the soil mesofauna groups' density and diversity, as well as their relationship with chemical attributes of a Yellow Oxisol being managed for fourteen years with biochar (BC) increasing doses. This study was undertaken at an Experimental Station of the National Institute for Amazonian Research, in Manaus-AM. The experimental design was in randomized blocks, with four doses of BCand four replications (blocks), totaling 16 experimental units. The largest (24) and smallest (18) number, of taxonomic groups was identified in soil with no, and with 120 Mg ha^{-1} BC, respectively. Groups density (181,217 individuals m^{-2}) showed not to vary significantly between treatments. This total was represented by Acari 80.70%, Collembola 6.76% and Formicidae 4.22%. Regression analysis revealed a significant, Shannon's diversity index, decrease with increasing BC dose, added to the soil. A similar trend was observed for the Collembola density C/N ratio, which decreased as the soil Al^{3+} content increased. Formicidae density increased with greater, soil P availability. Therefore, changes in soil chemical properties determine the mesofauna taxonomic groups, number and density, as well as each one's association degree with the evaluated treatments, since edaphic attributes define the resources necessary for their development.

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INTRODUCTION

Biochar is a recalcitrant material, produced from the thermal decomposition of numerous sources of organic waste, and its incorporation into agricultural soil has been proposed as a strategy to mitigategreenhouse gases anthropogenic emissions (Woolf *et al.* 2010; Gul *et al*. 2015). Furthermore, it has proved to increase some soils' aeration and water retention ability (Githinji 2014; Schulz *et al.* 2014), reduce Al^{3+}levels (Falcão *et al.* 2013), improve macronutrient cycling (Ventura *et al.* 2013) and raise, the crops productivity (Genesio *et al.* 2015; Cedano 2017). Even though there is an extensive literature pertaining to the effects that biochar exerts on the soil chemical and physical attributes, its action on the edaphic fauna has received little attention as compared to topics related to agriculture.Studies addressing the biochar action on soil biology have largely focused on microbial biomass (Lehmann *et al.* 2011); some of these studies have found that adding biochar to soils increases their microbial abundance and activity (Steiner *et al.* 2004; Birk *et al.* 2009; Domene *et al.* 2014).

Thus, research on the biochar influence on soil mesofauna is scarce in the literature (Weyers e Spokas 2014; Domene *et al.* 2015), which is surprising since some mesofauna groups have a direct effect on litter fragmentation and facilitators of groups of soil microorganisms, as is the case of Collembola and Acari (Griesang *et al.* 2016). Although different works with mesofauna have been published in different ecosystems in the region (Franklin e Morais 2005; Franklin *et al.* 2006; Acioli e Oliveira 2015; Oliveira 2009), the study on biochar is recent and mainly involves soil physical and chemical analyses, which have more recently, been focused on soil biology as well. Any impact on these groups is expected to, through a trophic effect, influence soil microbial communities, concomitantly with nutrient availability for plants (Lavelle *et al.* 2006; McCormack *et al.* 2013). In view of the above, biochar has been shown to be an alternative for improving some soils fertility due to its effect on their physicochemical and biological properties. However, most reports on these effects come from studies conducted in pots (Conti *et al.* 2018; Domene *et al.* 2015) which, when carried out in the field are shorttermed (Domene *et al*. 2014; Weyers and Spokas 2014), so these results may not be indicative of long-term conditions in biochar-modified soils. In these terms, the objective of this research is to evaluate mesofauna groups density and diversity, as well as their relationship with the chemical attributes of a Yellow Oxisol managed with increasing biochar doses for fourteen years.

MATERIALS AND METHODS

Study Area: This research is part of a long-term experiment, which has aimed to investigate biochar effects on macro and micronutrients availability together withcorn agronomic performance(Silva *et al*. 2009; Guimarães 2017) and cowpea (Noronha 2014; Falcão *et al*. 2013; Cedano 2017).This experiment was installed at the National Institute for Amazonian Research Tropical Fruits Experimental Station (02°37'20" South latitude and 060°02'45" West longitude) (Figure 1) during the 2006/2007 agricultural year. The climate of the region, according to the global classification of Köppen and Geiger (1928), is of type Af, with two well-defined seasons, a dry season from July to October and a rainy one from November to June. The average annual precipitation is 2286 mm, 80% relative humidity with temperature ranging from 23.3 °C to 31.4 °C and annual average of 26.7 °C (Alvares *et al*. 2013). The soil in the area was classified as typical Yellow Oxisol (Embrapa 2013).

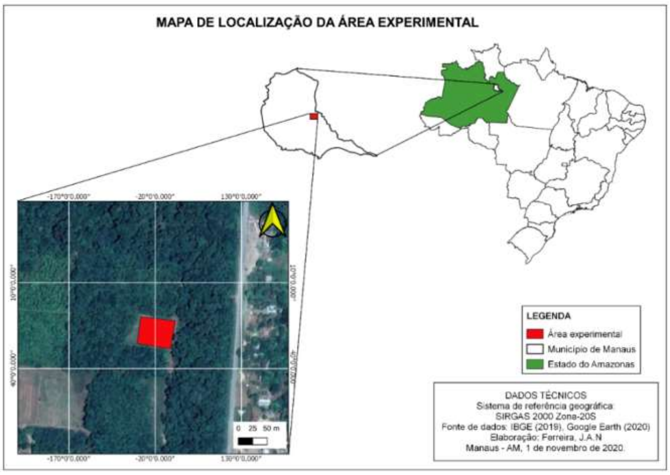


Figure 1. Geographic location of the experimental area in the National Institute for Amazonian Research's Tropical fruits Experimental Station

The opening and preparation of the area were carried out through conventional techniques, by cutting butnot burning the residues, aiming to test the biochar (BC) and saw dust (SD) doses effect in the soil later. BC, originating from different tree species,was obtained from charcoal plants in the metropolitan region of Manaus and, produced in ovens known as "hot tail", which can reach temperatures from 270 to 600 °C in the absence of oxygen (Swami *et al*. 2008), and bore the following chemical characteristics: 873.26 g kg^{-1}C; 8.93 gkg^{-1}N; 6.22 g kg^{-1}Ca; 1.30 g kg^{-1}Mg; 2.08 mg kg^{-1}K; 0.16 mg kg^{-1}P; 67.00 mg kg^{-1}Mn; 12.00 mg kg^{-1}Zn (Silva *et al.* 2009). SD, from the wood of differenttree species, was collected in a sawmill in the east side of the city of Manaus and, was already partially decomposed at the time of application. The experimental design was randomized blocks, in a split-plot scheme, main plot 0, 40, 80 and 120 Mg ha^{-1}BC, and sub-plot 0, 40, 80 and 120 Mg ha^{-1}SD, totaling 16 treatments, with 4 replications and 64 experimental units. Three months after the application of the treatments, a long-term experiment with rotation of corn (*Zea mays*) and cowpea (*Vigna unguiculata*), was started: 1st corn crop in July 2006; 2nd corn crop in March 2007; 1st cowpeacrop in June 2007; 3rd corn crop in January 2008; 2nd cowpeacrop in August 2008; 3rd cowpea crop in December 2012; 4th corn crop in April 2016; and 4th cowpeacrop in July 2016. Before the second corn planting, a complementary chemical fertilizer was added to the entire area, through the hurling of 66 kg ha^{-1} urea, 177 kg ha^{-1} triple superphosphate and 100 kg ha^{-1} potassium chloride; one month later, the equivalent of 133 kg ha^{-1} urea was applied to the surface next to the stem. Prior to the third corn planting one more NPK formulation, equivalent to 133 kg ha^{-1} urea; 350 kg ha^{-1} triple superphosphate and 200 kg ha^{-1} potassium chloride, was applied through hurling, once again. The area stayed fallow from 2012 to December 2015, when the first soil correction was carried out with 300 kg ha-^{1} of dolomitic limestone applied by hauling; and the last mineral fertilization was carried out March 2016, in order to meet the fourth corn and cowpea crops' demand. The experiments in the area were over in November 2016 and, it has been in a fallow state covered by colonizing plants with capimpacuã (*Holomolepisaturensis*), desmódio (*Alysicarpusovalifolius*) and mainlypueraria (*Pueraria phaseoloides*).

Experimental design: The present research took into account the residual effects of the application of biochar added to the soil in 2006, maintaining the experimental design of randomized blocks with four replications (blocks) and four BC doses (0, 40, 80 and 120 Mg ha^{-1}), totaling 16 experimental units.

Soil sampling and sample preparation: The samples were collected 10 cm deep, with the aid of a (5 cm x 5 cm) metal probe, at the useful area of each sub-plot (25 m²), in February 2019, and three collections were carried out, totaling 192 samples (Figure 2A).

Each sample was transferred to a properly labeled, 300 mg capacity lidded container and placed in a thermal Styrofoam box so as not to compromise the mesofaunastudy. when the collection was over, the samples were sent to the terrestrial invertebrate laboratory, of the Environmental Dynamics Coordination of the National Institute for Amazonian Research, where each sample was weighed before and after it was placed in the extractor device to obtain its fresh and dry weight level in order to ascertain the latter's retained water content value (Figure 2B) (Oliveira 1993).

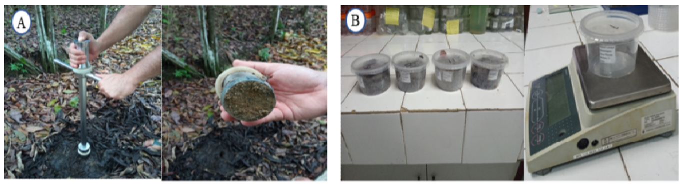


Figure 2. Metal probe used to collect soil samples at a depth of 0-10 cm (A). Weighing of soil samples to obtain the water content retained in the sample (B) (2019)

Mesofauna extraction and identification: For the extraction of the mesofauna, the adapted Berlese-Tüllgren extractor device, composed of boxes made of wood in the dimensions of 160 x 50 x 64 cm, divided into an upper and lower compartment by a Styrofoam sheet supported on wood for the placement of the funnels , and with doors to prevent night insects from being attracted to the light and causing damage to the samples; and mini open window in the door, screened with 1 cm mesh to avoid overheating inside the cabin was used (Karyanto et al. 2010). The 40 W lamps placed on the ceiling 30 cm away from the funnels, bearing a 2 mm mesh nylon screen to retain the litter/soil sample as well as allow the animals to go into 65 mL glass vials, which contain 80% ethyl alcohol, as a preservative solution, plus 5% glycerin to reduce the former's evaporation and function as a heat source. This cabinet bears the capacity for 30 samples (Figure 3A, B and C). Temperature was monitored daily, especially from the 4th day onwards, to prevent their temperature from exceeding 40 °C and to control the level of the liquid in the collecting glass vials. The purpose of maintaining this temperature limit is to avoid sudden, samples dehydration, thus allowing even slower moving animals, to reach the glass vial (Karyanto *et al.* 2010). The fauna was identified in Class, Order, Family and Genus (Triplehorn and Johnson 2011). An Opticam stereomicroscope binocular with a magnification capacity of 40 times, was used to identify and count soil mesofauna individuals (Figure 3 E, F, G e H). After counting the individuals, the values ob tained in the collector-measured surface area sample (0.00196 m²) were extrapolated to a one square meter site.

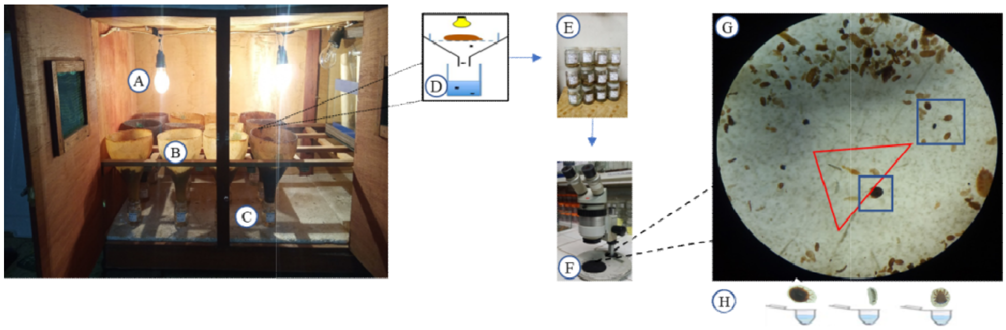


Figure 3. Berlese-Tüllgren Apparatus: lamp (A); funnel (B); 65 mL glass vial (C); extraction process detail (D). mesofauna Identificationand counting: vials containing mesofauna (E); stereomicroscope (F); blue and red-highlighted Acari and Collembola dominant groups, respectively (G); collection for Inpa (H) (2019)

Table 1. Properties of soil managed with 0, 40, 80, and 120 Mg ha^{-1} of biochar (2019)

Soil Properties		Biochar (Mg ha^{-1})			
		0	40	80	120
Gravimetric moisture (Ug)	(%)	41.12	41.26	45.32	41.48
pH in water		5.23	5.17	4.82	4.76
Potential acidity (H^{+}+Al^{3+})	($cmol_c$ kg^{-1})	3.72	4.42	4.76	4.90
Organic Matter (OM)	(g kg^{-1})	26.35	32.82	32.96	30.36
Phosphorous (P)	(mg kg^{-1})	7.78	12.8	12.46	8.74
Manganese (Mn^{2+})	(mg kg^{-1})	1.12	1.98	2.22	2.10
Zinc (Zn^{2+})	(mg kg^{-1})	0.32	0.40	0.37	0.42
Aluminum (Al^{3+})	($cmol_c$ kg^{-1})	0.55	0.63	0.66	0.74
Calcium (Ca^{2+})	($cmol_c$ kg^{-1})	0.64	1.03	0.71	0.71
Magnesium (Mg^{2+})	($cmol_c$ kg^{-1})	0.56	0.79	0.60	0.68
Exchangeable bases (SB)sum	($cmol_c$ kg^{-1})	1.22	1.91	1.33	1.41
Carbon nitrogen (C/N) ratio	(%)	14.16	13.92	12.64	12.36
Total nitrogen (TN)	(g kg^{-1})	1.10	1.41	1.51	1.45
Total organic carbon (TOC)	(g kg^{-1})	15.28	19.03	19.12	17.61
Iron (Fe^{3+})	(mg kg^{-1})	185.10	182.47	188.5	195.27
t	($cmol_c$ kg^{-1})	1.80	2.47	1.97	2.15
T	($cmol_c$ kg^{-1})	4.94	6.33	6.09	6.32
Aluminum Saturation (m)	(%)	33.1	24.82	32.85	33.94
Bases Saturation (V)	(%)	24.81	29.32	21.81	22.49

T = cation exchange capacityat pH 7; t = effective cation exchange capacity

Soil Chemical Analysis: Mesofauna study samples for the soil chemical analyses were carried out at the Thematic Laboratory of Soils and Plants (LTSP) of the National Institute for Amazonian Research INPA according to the methodology described by Embrapa (2013), were collected nearby their collecting sites.Soil samples were air-dried and sieved through a 2 mm mesh to obtain air-dried fine earth (ADFE). These samples were used to determine the following chemical variables: pH in water, potential acidity (H + Al), total organic carbon, total nitrogen, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), aluminum (Al), iron (Fe), zinc (Zn) and manganese (Mn). The pHin water was determined using a potentiometer, by means of a combined electrode immersed in the soil/water suspension in a 1:2.5 ratio. To obtain the potential acidity (H^{+} + Al^{3+}) extraction was performed with calcium acetate [$Ca(C_2H_3O_2)_2$] 0.5 mol L^{-1} as well as its determination through titration with sodium hydroxide (NaOH). Soil organic carbon (SOC) was analyzed by the Walkley-Black method and soil organic matter (SOM) was estimated by multiplying the SOC concentration by 1.72, “Van Bemmelen” factor. Total nitrogen (TN) was determined by the Kjeldahl method. Extractions were performed with 1 mol L^{-1} KCl solution so as to conduct the Ca^{2+}, Mg^{2+} and Al^{3+} analyses. While P, K^{+}, Fe^{3+}, Zn^{2+} and Mn^{2+} were extracted with Mehlich-1 solution (HCl 0.05 M + H_2SO_4 0.0125 M). P concentrationin the extract was determined using a spectrophotometer, by calorimetry with ammonium molybdate and ascorbic acid. Ca^{2+}, Mg^{2+}, K^{+}, Fe^{3+}, Zn^{2+} and Mn^{2+} in the extract were determined by flame atomic absorption spectrophotometry. The extractable Al3+ was determined by titration with sodium hydroxide (NaOH) solution. The sum of Exchangeable bases (SB); effective cation exchange capacity (t); aluminum saturation percentage (m); cation exchange capacity at pH 7 (T) and CTC base saturation at pH 7 (V), was calculated based on the obtained data.

Statistical analysis: Discrepant data (outliers) existencewas assessed by the Grubbs test. Errors normality by Shapiro-Wilks testand variance homogeneityby Bartlett test. Biochar doses effecton mesofauna groups density was evaluated by analysisof variance (ANOVA) and means compared by Duncan testat 5% likelihood level. Statistical analyseswere performed using R 2.13 software (Development Core Team, 2012). Richness, dominance, Shannon and Pielou index were calculated using PAST 2.17c software (Hammer *et al.* 2001). Regression equations were adjusted to the studied variables, in order to determine mesofauna groups density behavior, due to any alterations, biochar doses come to exert on soil variables.

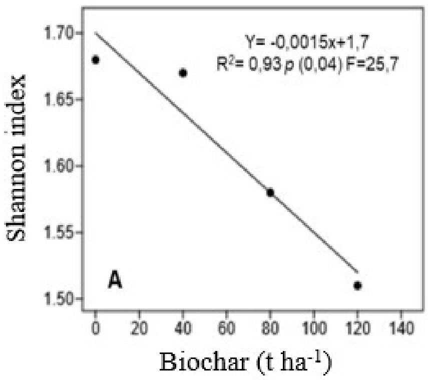
RESULTS AND DISCUSSION

Mesofauna Diversity and density: The density of the mesofauna groups was similar in the doses of biochar (BC), which did not differ in the general density of invertebrates, either. A total of 181,217 individuals m^{-2} were collected, representing 23 taxonomic groups, Acari Oribatida (57.537), Archigozetes sp. (12,753), Outros Acari (76,292), Collembola (12,286) and Formicidae (7,657) occurred dominantly in all treatments, together they represented approximately 91.7% of the total invertebrate density (Table 2). A total of 23 groups were recorded, with the highest richness (21 groups) occurring in the soil with no BC and the lowest one (16 groups) in that managed with 120 Mg ha^{-1} BC, with the latter differing from the former due to its lower C/N ratio, higher active acidity, and Al^{3+} content, especially Mn^{2+}, which went from 1.12 (0 Mg ha^{-1} BC) to 2.10 $cmol_c$ kg^{-1} (120 Mg ha^{-1} BC). These results corroborate studies that show mesofauna groups are sensitive to soil, chemical attributes changes (Baretta *et al.* 2014; Pompeo *et al.* 2016). As to the Shannon diversity index (H) (Table 2), the lowest values were recorded in the presence of BC.

Table 2. Composition and density (individuals m-2) at 10 cm deep soil mesofauna taxonomic groups, present inaYellowOxisol altered with increasing biochar doses (2019). S= richness; H=Shannon; J = Pielou

Taxonomic groups	Biochar (Mg ha^{-1})				TOTAL
	0	40	80	120	
HEXAPODA					
Collembola	4,601	3,086	2,775	1,824	12,286
INSECTA					
Thysanura	28	0	14	0	42
Coleoptera	1,260	410	892	354	2,916
Diptera	142	127	269	113	651
Homoptera	14	156	127	326	623
Hemiptera	184	57	99	170	510
Thysanoptera	42	28	0	0	71
Hymenoptera	14	0	0	0	14
Formicidae	1,585	2,250	2,151	1,670	7,657
Psocoptera	127	85	170	142	524
Isoptera	28	0	0	0	28
Trichoptera	0	0	14	0	14
Blattodae	0	14	0	0	14
ARACHNIDA					
Acari Oribatida (out.)	14,919	11,748	19,122	11,748	57,537
Archigozetes sp	3,723	750	5,180	3,100	12,753
(Outros Acari)	20,311	13,206	23,581	19,193	76,292
Araneae	396	170	410	127	1,103
Pseudoscopionida	42	85	85	14	226
CRUSTACEA					
Isopoda	85	28	142	71	326
Copepoda	14	0	14	0	28
CHILOPODA	85	198	198	198	679
DIPLOPODA	368	184	198	311	1,061
Polyxenidae	354	609	679	198	1,840
SYMPHYLA	311	255	212	127	906
PAUROPODA	1,104	1,273	326	340	3,043
OLIGOCHAETA	57	0	14	0	71
TOTAL	49,796	34,720	56,675	40,026	181,217
S	21	18	20	16	23
H	1.680	1.673	1.580	1.506	
J	0.528	0.558	0.507	0.521	
D	0.273	0.274	0.299	0.326	

Richness (S); ShannonIndex (H); Pielou Index (J); and Dominance (D)



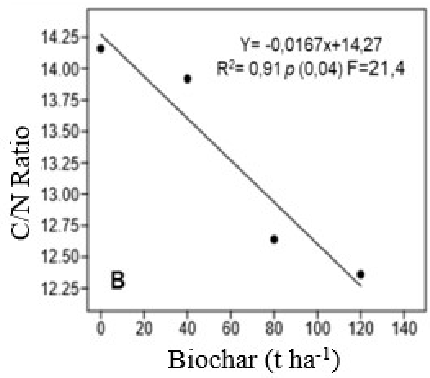


Figure 4. Shannon index (A) and C/N ratio (B), in a Central Amazonian Yellow Oxisol managed with Biochar increasing doses (2019)

As can be seen in Figure 4A, when correlating Shannon index to BC doses one finds that the higher the BC dose incorporated into the Yellow Oxisol the significantlylower, its mesofauna diversity. BC doses showed similar response when it came to carbon and nitrogen (C/N) ratio (Figure 4B). This result may indicate that, BC-altered soil properties have benefited plant species that provide organic residues with a lower C/N ratio, such as legumes, which are efficient in P absorption (Malavolta 1981), as well as able to colonize, soil plots bearing this element's lower availability, as those presenting 80 and 120 Mg ha^{-1} of BC. On the other hand, they are easily decomposing species, and, consequently, inefficient, when one endeavors to protect the soil (Aita *et al*. 2001). Thus, the lower mesofauna groups diversity in regards to BC doses may be related to soil cover, since both the quantity and quality of organic residues added to the soil influence the presence of edaphic fauna (Carrillo *et al*. 2011; Lima *et al*. 2010), either controlling soil moisture and temperature, or as a food source (Pompeu *et al*. 2016; Santos 2016; Machado *et al*. 2019). Contrary to the H index decreasing linear response (Figure 4A), the dominance index (D) showed an increasing trend in relation to BC doses added to the soil, with the highest values, 0.299 and 0.326, to be found in soil managed with 80 and 120 Mg ha^{-1} of BC, respectively. Just like Pielou evenness index (J), its lowest value (0.507) was observed in soil with 80 Mg ha^{-1} of BC (Table 2), meaning a large difference in abundance between the studied groups, that can be seen through the predominance of, Acari (Oribatida, Archigozetes sp. and Outros Acari), Collembola and Formicidae, with Acari to be responsible for 86% of all the individuals sampled in this treatment. These results, especially those pertaining to pH and associated properties control reinforce the soil management full understanding (Baretta *et al*. 2014; Machado *et al*. 2019; Pompeo *et al*. 2016a; Socarrás 2013), Mn^{2+} and

Al^{3+} contents (increased with BC doses), can affect the stability of invertebrate communities present in the soil just as the latter ones may be used to evaluate soil properties changes, concomitantly. Taxonomic groups density and soil parameters: The lowest invertebrate density (35,146 individuals m^{-2}) was found in soil managed with 40 Mg ha^{-1} BC, which bore lower moisture and organic matter content, higher pH, as well as more elevated, Ca^{2+}, Mg^{2+} ions and K^{+} concentrations. These soil attributes, with the exception of moisture and organic matter, were lower in soil with 80 Mg ha-1BC, which presented the highest individual density (56,675 m^{-2}) (Table 2). Organic matter quantity, moisture content and pH are soil attributes, that exhibit great influence on the density of most the studied mesofauna (Socarrás 2013). The studies by Baretta *et al*. (2014) and Pompeu *et al*. (2016), for example, confirm that, the establishment, abundance and diversity of these invertebrate groups have a strong association with soil pH, since they can affect food resources availability along with affecting and limiting the presence of some Collembola species related to essential ions present in the soil solution.

The highest Collembola (4,601 individuals m^{-2}) density was found in the absence of BC and the lowest one (1,824 individuals m^{-2}) in soil managed with 120 Mg ha^{-1} BC (Table 2). When correlating the Collembola density with BC doses, a negative linear regression with R^2 of 0.94, was found indicating that adding BC to the soil provided an unfavorable environment for these organisms' population (Figure 5A). This result is probably related to the soil pH, which decreased concomitantly with the applied BC dose, passing from 5.23 to 4.75 in the soil with 120 Mg ha^{-1} of BC, which was accompanied by a soil Al^{3+} increased concentration. Collembola community sensitivity to soil acidity and its associated properties, such as Ca^{2+}, Mg^{2+} and Al^{3+} ions concentration was observed by other authors, as well (Chagnon *et al*. 2000, 2001; Cutz-Pool *et al*. 2007; Ferreira *et al*. 2019; Machado *et al*. 2019). Chagnon et al. (2001) observed that increasing soil pH and itsrelated properties, such as increasing Ca^{2+} and Mg^{2+} content, and decreasing exchangeable Al^{3+} value, were accompanied by a decrease in abundance and dominance of the epigeic species *Sminthurinusmacgillivrayi, Sminthurideslepus* and *Hypogastrura sp*. and endogeic species *Folsomiapenicula,*

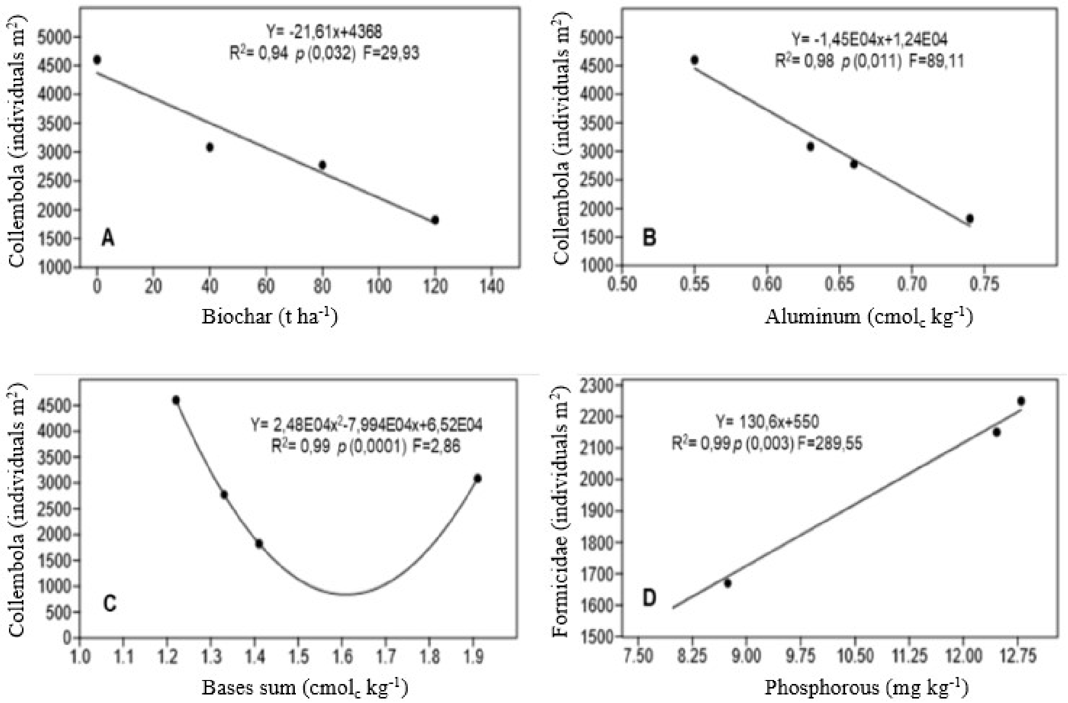


Figure 5. Collembola density as a function of Biochar doses (A); Aluminum (B); Bases sum (C) and; Formicidae density as a function of Phosphorous content (D) in a Biochar-managed Central Amazonian Yellow Oxisol (2019)

Acari predominated in the experimental area, representing 80.89% of the studied invertebrate's general density. Out of Acari total density (146,582 individuals m^{-2}), 38.79% were represented by the suborder Oribatida (Acari Oribatida (outros) and Archigozetes sp.), which are considered important organic matter decomposers. Mites represent the mesofauna most abundant group, in several environments, with oribatid being the most dominant one, sometimes representing over 50% of the captured mites total density (Adis *et al*. 1989; Ribeiro and Schubart 1989; Oliveira 1993; Morais *et al*. 2010; Carvalho 2014; Santos 2016). For instance, Adis *et al*. (1989), in Campinaranaforest soil, recorded that 55.9% of the collected arthropods belonged to the Acari group, of which about 51% were represented by Oribatida. While, out of the total number of mites collected, Ribeiro and Schubart (1989) found 77% and 54% of oribatid in primary and secondary forest, respectively; Oliveira (1993) found 80% of Archigozetes in an okra plantation when studying four different floodplain soil environments. Collembola was the second group in number of individuals per square meter, representing 6.78% of the mesofauna found in the (treatments) four BC doses. Studies carried out in various environments by Teixeira and Silva (1997), Baretta *et al*. (2008), Bellinger *et al*. (2015) and Santos (2016) showed Collembola to be the second most frequent group.

Microsotomaachromata and *Dagamaea tenuis*, while *Isotomiella minor* (endogeica) and *Tomocerusflavescens* (epigeica) increased theirdominance. Pompeu et al. (2016) also found an increase in the abundance of some Collembola species in soil with high Ca^{2+} and Mg^{2+} ions levels.The present study has demonstrated the soil, Al^{3+} concentrationincrease, to be accompanied by a significant, Collembola group abundance, decrease ($p < 0.01$) (Figure 5B), indicating the Al^{3+} elevation not to be favorable for some dominant species in BC- lacking soil. On the other hand, when correlating these organisms'density with the base sum (Ca^{2+}, Mg^{2+} and K^{+}), a quadratic regression was found (Figure 5C), demonstrating some Collembola genera specificity for a certain base sum range, as that found in a preliminary study carried out in the same experimental area, in which Collembola *Folsomides*and *Folsomina*genera abundance decrease, was observed in the BC-managed soil, which was characterized by high, Ca^{2+}, Mg^{2+} and K^{+}levels (Ferreira et al. 2019). One of the answers to these results concerns the effect these chemical elements have on the fungi and bacteria community, which may, depending on their concentration in the soil, negatively influence this community, thus affecting species of Collembola that feed on these microorganisms (Oliveira 1994). In this way, biochar, through the effect it has on the chemical properties of the soil, may favor some species of Collembola over others. The Formicidae group was also present in all evaluated treatments and, its density represented 4.22% of the obtained mesofauna, thus occupying the third position in number of individuals per square meter. The highest densities, were the ones obtained in the 40 and 80 Mg ha^{-1} BC-managed soil, which were characterized by higher P values. When considering there to have been an increase in these organisms' density at higher P concentrations in the soil, the effect of the former on the latter, was correlated when considering there to have been an increase in these organisms'density at higher P concentrations in the soil, the effect of the former over the latter, was correlated. This correlation's significant results are presented inFigure 5D. As it can be seen, a positive linear regression was found with R^2 of 0.99, showing the soil P content increase to have significantlycontributed to the Formicidae density rise ($p < 0.003$). The study by Dunxiao et al. (1999) has also shown Formicidae to be positively correlated with the high, available P concentration, which corroborates this research's findings. Higher available P, concentrations are likely to have propitiated favorable conditions for the trophic relationships'stability necessary for the occurrence of certain genera such as *Pyramica* and *Strumygenys*, which are specialized Collembola predators (Masuko 2009). The other invertebrates' groups (20) corresponded to a participation of 8.32% of the total, collected mesofauna. Most of this percentage (5.50%) was represented byPauropoda, Coleoptera, Polyxenidae, Araneae and Diplopoda groups, which, despite their reduced abundance, have an important function concerning ecological balance and trophic relationships, and also able to act in the biological control of other populations considered to be pests in agrosystems (Rodrigues et al. 2010; Brito et al. 2016; Marques et al. 2014).

CONCLUSIONS

In ascending order, Acari, Collembola and Formicidae were the groups that reached the highest densities. Soil managed with 40 Mg ha^{-1} of biochar provided better chemical characteristics that culminated in a greater mesofauna communities' uniformity. Collembola group proved to be sensitive to small Al^{3+} content variations in the soil, since its density decreases as this ion soil concentration increases. Bases (Ca^{2+}, Mg^{2+} and K^{+}) sum variations caused significant, Collembola density oscillations, which may be related to some genera preference for a certain bases sum range.
Formicidae group density showed to be higher, as the soil P availability, was increased.

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