academicJournals

Vol. 11(36), pp. 3404-3411, 8 September, 2016
DOI: 10.5897/AJAR2016.11213
Article Number: 5487DBA60330
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Soil fauna dynamics affected by decomposition of different legume combinations in alley cropping systems in São Luís, Maranhão, Brazil

Nárgila de Moura, Raimunda Nonata de Lemos*, João Thiago R. de Sousa, Albéryca Stephany de Ramos, Ester do Amaral, Emanoel de Moura and Mario Luiz Mesquita

Graduate Program in Agroecology, Maranhão State University, São Luís, Maranhão 65054-970, Brazil.

Received 11 May, 2016; Accepted 22 August, 2016

The objective of this study was to evaluate the temporal composition of epigeous fauna during decomposition of different legume combinations in alley cropping systems. Two legume species with high quality waste *Leucaena leucocephala* (*Leucaena*) and *Cajanus cajan* (Pigeon pea), and two species of low quality waste *Clitoria fairchildiana* (Sombrero) and *Acacia mangium* (*Acacia*), were combined forming six treatments: Sombrero + Pigeon pea (S + PP); *Leucaena* + Pigeon pea (L + PP); *Acacia* + *Leucaena* (A + L); Sombrero + *Leucaena* (S + L); *Acacia* + Pigeon pea (A + PP) and control (without legumes). We used the litter bag method to evaluate waste quality. Each bag was filled with 20 g of leaves of the two combined legumes and distributed in the treatments and were withdrawn on the day of pruning and at 3, 6, 10, 15, 30, 60 and 90 days after legume pruning. Two pitfall traps were used to capture epiedaphic fauna in each treatment. Eight evaluations were done based on the date of legume pruning. The initial amount of N was higher in the L + PP treatment (29.31 gKg^{-1}), which showed the highest decomposition constant, providing the fastest release of N in the soil; and presenting the lowest C/N ratio. The highest polyphenol content was found in A + L (4.84%). The soil fauna under different vegetation covers was composed mainly of Aranae, Coleoptera, Diptera, Formicidae, Coleoptera larvae, mites and Collembola; the latter two being the more abundant in all samples. The soil fauna group richness varied during the time of decomposition; the greatest diversity was recorded at 60 days after the legume pruning due to group homogeneity.

Key words: Arthropods, mites, springtails, soil ecology, decomposition.

INTRODUCTION

Alley cropping consists of a production system using dense lines of arboreal or shrubby green manures with high regrowth capacity, and crops of agronomic interest planted between the legume rows; this system is advantageous for increasing biomass production, soil covering and improving erosion control. Moreover, it

*Corresponding author. E-mail: rlemos@cca.uema.br. Tel: +55 98 9972 9504.

improves soil physical, chemical and biological properties (Vasconcelos et al., 2012). Soil is the richest habitat of the terrestrial ecosystem and its fauna plays an essential role in its functioning and balance as well as in the maintenance of the food chain and energy flow in the organic waste decomposition dynamics (Morselli, 2007; Nunes et al., 2009). As a result of this connection with the processes occurring in the soil and its enormous sensitivity to changes in the environment, soil fauna composition reproduces the ecosystem functioning pattern (Vasconcelos et al., 2012).

Soil fauna abundance, diversity, and interference are indicators of soil quality (Cunha Neto et al., 2012), and significantly improve the soil physical and chemical properties in areas subjected to recovery processes (Morselli, 2007). Thus, well managed degraded areas increase the soil fauna population density, benefiting the establishment of soils suitable for agriculture (Nunes et al., 2009).

In addition, legumes act directly on the soil fauna population, promoting nutrient cycling, extraction and mobilization into the deeper soil and subsoil layers, higher Cation exchange capacity (CEC) values, higher organic matter content, increase in microbial biomass carbon, increase in microbial coefficient, reduction of soil density and increase in macroporosity and total porosity (Silva et al., 2013). These effects are related to organic waste maintenance on the soil (Cunha Neto et al., 2012).

Therefore, due to importance of alley cropping for the humid tropics, this study aimed to evaluate the soil fauna composition under different vegetation covers in the State of Maranhão, Northeastern Brazil.

MATERIALS AND METHODS

Study area

The study was conducted in São Luís, Maranhão State, Northeastern Brazil (2º30′S and 44º18′W). The soil of the study area is classified as Ultisol Yellow Dystrophic Hapludalf (Embrapa, 2013).

Experimental design

The alley cropping trial was established in 2002 in a randomised complete block design, with six treatments consisting of planting four legume species used for mulching in different combinations, and replicated four times. Two legumes of high- quality waste, *Leucaena leucocephala* (Leucaena) and *Cajanus cajan* (Pigeon pea) and two of low quality, *Clitoria fairchildiana* (Sombrero) and *Acacia mangium* (Acacia) were used. Plants were sown in double rows in such a way that each plot received two types of residue resulting from the combination of two legume species. Thus, treatments were: Sombrero + Pigeon pea (S + PP); *Leucaena* + Pigeon pea (L + PP); *Acacia* + *Leucaena* (A + L); Sombrero + *Leucaena* (S + L); *Acacia* + Pigeon pea (A + PP) and control (without legume species). The crops were sown in single rows, 0.5 m between plants and 4 m between rows, in 21 × 4 m plots.

Cassava (*Manihot esculenta*) was planted in 2006 between the legume rows at 12 × 4 m, representing 20 plants per plot. Fertilisers were used at the rate of 80 kg ha^{-1} of P_2O_5, 40 kg ha^{-1} of K_2O and 3 kg ha^{-1} of Zn. In January, 2008, the legume plants were pruned at 50 cm height and the pruning parts were weighed and spread uniformly on the soil surface of each treatment plot.

Residue evaluation

Litter bags of 35 × 35 cm with 2-mm openings were used to evaluate residue quality. Each bag received 20 g of mixed leaves of the two legume species and was placed in contact with the soil in the respective treatments (except control). Bags were removed from the plots in the day of pruning, and at 3, 6, 10, 15, 30, 60 and 90 days after legume plant pruning. The resulting material was carefully cleaned and oven dried at 60°C until a constant weight was obtained, and then weighed, grounded, and subjected to chemical analysis.

Nitrogen content was analysed according to the methodology proposed by Tedesco (1982), in which samples go through sulfuric digestion and N content is evaluated by vapor drag followed by titration. Organic carbon was evaluated using the method proposed by Sparks et al. (1996), which submits samples to potassium dichromate and sulfuric acid, followed by titration. Total polyphenols were extracted using the Folin-Denis method, which consists of total extraction of polyphenolic compounds, including condensed and hydrolysable, with a 50% methanol solution (Anderson and Ingram, 1993).

Fauna evaluation

Epiedaphic samplings were made two days before pruning (dbp) and at 3, 6, 10, 15, 30, 60 and 90 days after pruning (dap). Two traps were placed 1 m apart at the center of each plot, buried in the soil and filled with 200 ml of water with 2 drops of detergent. To prevent rainwater from directly entering, the trap opening was protected by a plastic dish suspended approximately 5 cm from soil level by wooden stakes. Traps remained 48 h in the field. Collected materials were washed and the organisms were placed in 70% alcohol and identified in great taxonomic groups using entomological keys.

Statistical analysis

Decomposed dry matter in function of time was computed by the difference between initial mass weight at the end of each sampling, and the percent of the remaining computed dry matter. The decomposition constant K was computed according to Olson (1963) with the exponential model of the dry matter in bags in time zero (t = 0): $X_0 . e^{-kt}$, where Xt = weight of the dry matter remaining after t days, X_0 = dry matter placed in bags at time zero (t = 0), after calculation of the mass remaining throughout the period.

Analysis of variance was carried out to evaluate the difference between decomposition constant for each combination of legume species using the Tukey test at 5% probability for mean comparisons. Soil fauna diversity was calculated using the Shannon - Wiener Diversity Index and the equitability. Orders of insects relative frequencies was obtained and those with values lower than 1% were grouped as “others.” The taxonomic groups were submitted to multivariate method and cluster analysis, to describe similarity among treatments.

RESULTS AND DISCUSSION

The initial amount of N was higher in the treatment L +

PP (29.31 g Kg^{-1}) followed by A + L (26.07 g Kg^{-1}), S + PP (25.63 g Kg^{-1}), A + PP (25.38 g Kg^{-1}) and S + L (23.42g Kg^{-1}). The highest polyphenol content was found in A + L (4.84 %), followed by L + PP and S + L (3.92 and 4.01%, respectively) and the lowest rates were in S + PP and A + PP (both with 3.35%). The C/N ratio was lower for L + PP (16 g Kg^{-1}) followed by A + L (17 g Kg^{-1}), S + L (18 g Kg^{-1}) A + PP (19 g Kg^{-1}) and S + PP (19 g Kg^{-1}) (Table 1).

The *Leucaena* and *Gliricidia* species have a robust capacity for regrowth; they can produce large amounts of high-quality biomass with high N and low lignin and polyphenol contents, thus contributing to higher production (Mafongoya et al., 1997). The C/N ratio reflects the speed by which the material decomposition can be processed. The residues with C/N ratios less than 25 (legumes) decompose faster; high contents results in lower C/N (Ferraz Júnior, 2004).

It was observed that in all evaluations, the treatments with the highest number of individuals were with *Acacia* or Sombrero (2 dbp and 3, 15, 30, 60 and 90 dap). These treatments also had the highest residue additions and the highest C/N relationship and the amount of polyphenols. The soil fauna variation behavior between treatments characterizes the influence of waste with different chemical compositions, because the residues with a higher C/N relationship rate are less vulnerable to the effect of decomposition agents, accelerating the loss (Resende et al., 2013). The social insects, saprophytes and herbivores, are among the few organisms able to feed on residues of low-quality material, indicating that the litter quality determines the ability of saprophagous organisms to release nutrients, influencing the faunal community size (Santos et al., 2008; Resende et al., 2013).

Regarding the constant decomposition of legume combinations, the treatment L + PP had the highest value, but it was not statistically different from S + PP, which, in turn, did not differ from the other treatments. It was expected that the treatment L + PP would be different from the treatments A + L, S + L and A + PP due to their smaller C/N relationship (Figure 1). The decomposition rates in this study were lower than the k values (1.24 and 1.80) to litter found for *Acacia mangium* by Castellanos-Barliza and León (2011). The modified microhabitat increases growth and development of the soil fauna. Furthermore, it facilitates litter decomposition, nutrient release and promotes biotic interactions (Wang et al., 2010).

A total of 78,210 individuals, distributed in 31 groups were found throughout the study period. The highest number of individuals (5,938 individuals/trap) was observed 2 dbp in the treatment A + L, where they were most abundant (Figure 2).

Before legume pruning, many weeds and remaining pruning material from previous years, such as branches, and trunks, were observed, particularly in the treatments with *Acacia* and Sombrero, and senescent leaves resulting from legume regrowth. The spontaneous plants present relevant ecological functions for the agroecosystems. According to Altieri et al. (2003) they are important, especially for biological control by providing an environment serving as support for pest natural enemies such as predators and parasitoids of many crops of economic importance, providing pollen, nectar, shelter and a microclimate favourable to their optimal development conditions.

At 3 dap, the number of arthropods decreased dramatically (1,611 individuals/ trap), with treatment A + L showing higher abundance. This marked decrease in the number of organisms may have occurred because the vegetation cover may have increased the foraging area of arthropods in each treatment, favouring the dispersion of soil fauna and decreasing their probability of falling into the traps. Santos et al. (2008) observed significant differences in an arthropod population with the use of cover crops compared to fallow. Thus, it is possible that the cover crops used to protect the soil significantly affected the soil fauna community.

At 15, 30 and 60 dap, it was observed that the abundance of arthropods declined sharply, with 2,288, 1,198 and 825 individuals/trap, respectively, but at 90 dap, the amount of organisms increased, on average, to 1,419 individuals/trap, highlighting the treatment A + PP as the most abundant (Figure 2); in this period, it was observed that the plant material was already at an advanced decomposition stage. The final decomposition stage was characterized by gradual decomposition of the most resistant compounds, which is carried out by actinomycetes and fungi activity; thus, there may be an increase in the amount of bacteria and fungi (microorganism decomposers) to decompose the material (Eisenhauer et al., 2010), and these bodies can lead to an increase in the micro herbivorous arthropod abundance and/or species richness and consequently, their predators (such as Collembola and some mites) that were the most abundant groups, causing the so-called bottom-up control (Kaspari, 2004).

The Collembola and mites were more abundant in most collections in all treatments. Except, in the treatments L + PP (23.5±4.3) and the control (25.3±8.9) at 60 dap, Formicidae presented the highest average (Table 2). Collembola and Acari play an important role in the soil, because they are predators of some soil organisms, especially the microbiota, besides assisting in the soil organic matter decomposition and regulating microorganism populations, particularly the fungi (Baretta et al., 2008). Feeding specificity, weatherproof resistance levels, reproductive biology and dispersal capacity are considered possible reasons of higher occurrence of such bodies in certain areas. Some studies show that these two groups are present at various levels of organic matter decomposition (Hoffmann et al., 2009; Monroy et al., 2011).

Table 1. Chemical composition and dry matter resulting from the legume combinations in the alley cropping system.

Treatments	C/N*	C (g kg^{-1})	N (g kg^{-1})	Polyphenol (%)	Dry matter (Mg/ha)**
Sombrero + Pigeon pea	19	497.55	25.63	3.35	4.92
Leucaena + Pigeon pea	16	485.26	29.31	3.92	0.78
Acacia + *Leucaena*	17	440.22	26.07	4.84	6.42
Sombreiro + *Leucaena*	18	415.65	23.42	4.01	5.71
Acacia + Pigeon pea	19	472.98	25.38	3.35	5.64

*Carbon/Nitrogen ratio; **Megagram/ha.

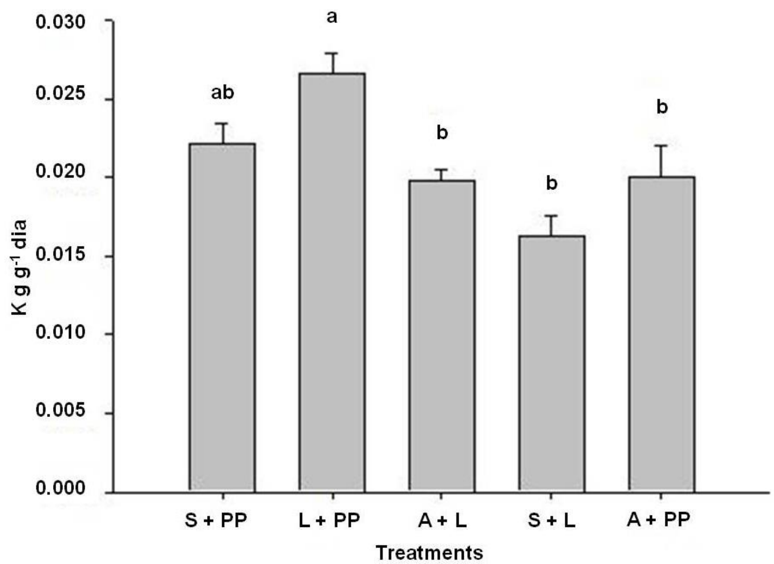

Figure 1. Decomposition constant (K) of legume combinations in the alley cropping systems. *Treatments with the same letter in columns are not statistically different by Tukey test at 5%. Error bars show the standard deviation.

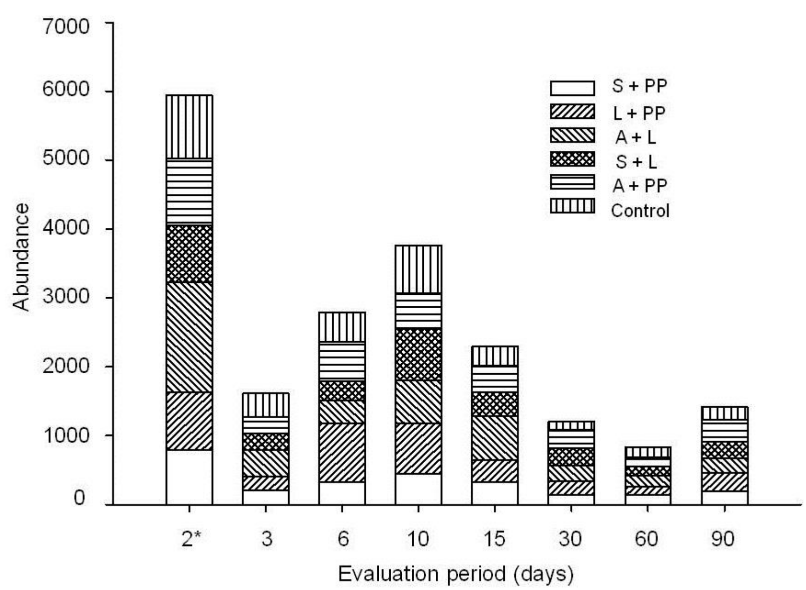

Figure 2. Number of arthropods collected in legume combinations in the alley cropping system. *Two days before legume pruning.

Table 2. Composition (%) of edaphic arthropod community in legume combinations in the alley cropping system.

Groups	Days after pruning							
	2*	**3**	**6**	**10**	**15**	**30**	**60**	**90**
Sombrero + Pigeon pea								
Acari	31.54	30.31	14.76	11.36	18.26	39.10	24.53	6.83
Aranae	0.51	5.19	1.81	1.83	3.62	2.42	8.87	2.40
Collembola	58.91	27.48	67.43	68.18	53.89	25.61	16.60	69.15
Coleoptera	1.24	3.54	4.79	4.49	3.70	6.40	20.19	4.93
Diptera	0.63	2.36	2.12	1.77	5.28	1.73	2.64	2.15
Formicidae	5.20	23.00	4.71	3.82	6.19	12.46	14.15	6.95
Coleoptera larvae	0.41	0.94	0.63	4.55	3.85	0.87	1.51	0.88
Others	1.55	7.19	3.30	3.99	5.21	11.42	11.51	6.70
Leucaena + Pigeon pea								
Acari	39.60	22.81	8.55	18.54	24.32	44.37	19.61	23.36
Aranae	1.01	3.80	1.72	1.18	4.55	3.10	4.74	3.93
Collembola	50.07	40.05	84.44	62.02	41.55	25.61	16.38	57.51
Coleoptera	1.09	4.18	0.41	3.43	6.78	4.66	15.95	2.75
Diptera	0.30	5.20	0.52	3.43	7.18	3.36	3.45	1.18
Formicidae	6.48	14.32	2.18	4.12	6.86	12.68	20.26	6.08
Coleoptera larvae	0.09	0.38	0.47	3.05	2.79	1.55	1.29	0.10
Others	1.36	9.25	1.72	4.23	5.98	4.66	18.32	5.10
Acacia + Leucaena								
Acari	35.66	45.31	17.03	23.30	51.65	67.11	40.67	20.09
Aranae	0.33	1.56	1.58	1.69	1.61	1.86	3.50	1.46
Collembola	59.21	21.32	62.27	53.83	27.48	12.72	16.50	62.63
Coleoptera	0.39	4.50	5.18	3.85	3.11	3.73	7.17	2.02
Diptera	0.30	3.65	2.78	4.83	6.21	1.43	4.50	1.91
Formicidae	3.47	17.86	5.93	5.82	4.17	7.68	14.33	8.19
Coleoptera larvae	0.03	0.59	1.58	2.28	2.59	1.10	1.33	0.22
Others	0.61	5.22	3.68	4.40	3.18	4.39	12.00	3.48
Sombrero + Leucaena								
Acari	51.31	19.39	19.87	7.83	10.93	34.42	25.91	13.11
Aranae	0.72	4.21	1.80	1.28	3.77	2.78	7.43	3.64
Collembola	41.09	50.16	57.73	71.48	50.91	43.25	27.54	63.37
Coleoptera	1.23	3.58	5.85	4.56	3.84	3.27	8.15	3.95
Diptera	0.24	4.32	2.97	4.15	10.43	2.58	2.90	1.77
Formicidae	3.39	10.43	5.22	3.64	6.52	8.93	15.76	5.31
Coleoptera larvae	0.15	1.37	1.71	4.52	9.92	0.69	0.54	0.73
Others	1.86	6.53	4.86	2.53	3.69	4.07	11.78	8.12
Acacia + Pigeon pea								
Acari	39.17	24.38	10.84	26.52	23.62	67.27	42.42	56.30
Aranae	0.62	4.75	1.10	1.84	3.04	1.62	4.18	2.91
Collembola	55.91	45.97	79.29	53.57	56.68	16.13	23.74	26.46
Coleoptera	0.54	3.82	1.85	3.77	2.15	3.05	2.86	1.18
Diptera	0.21	3.62	0.88	2.46	4.88	1.81	3.96	1.18
Formicidae	2.57	7.02	2.38	4.44	4.50	3.63	10.33	2.99
Coleoptera larvae	0.05	0.10	0.35	1.40	2.15	0.67	0.66	0.08
Others	0.93	10.33	3.31	5.99	2.98	5.82	11.87	8.90
Control								
Acari	9.39	13.10	20.61	12.90	16.17	16.07	13.76	6.71
Aranae	0.33	1.84	0.81	1.25	3.93	1.90	7.19	2.01
Collembola	75.87	61.96	59.00	72.81	49.44	54.97	30.60	70.20
Coleoptera	0.87	1.91	3.42	1.65	3.08	5.50	9.45	1.34

Table 2. Contd.

Diptera	0.36	1.55	3.29	1.93	6.92	3.38	4.93	1.34
Formicidae	11.90	13.39	8.15	5.12	12.99	12.47	20.74	10.74
Coleoptera larvae	0.15	2.28	1.45	0.50	1.78	0.42	2.67	0.54
Others	1.13	3.97	3.27	3.83	5.70	5.29	10.68	7.11

*Two days before legume pruning.

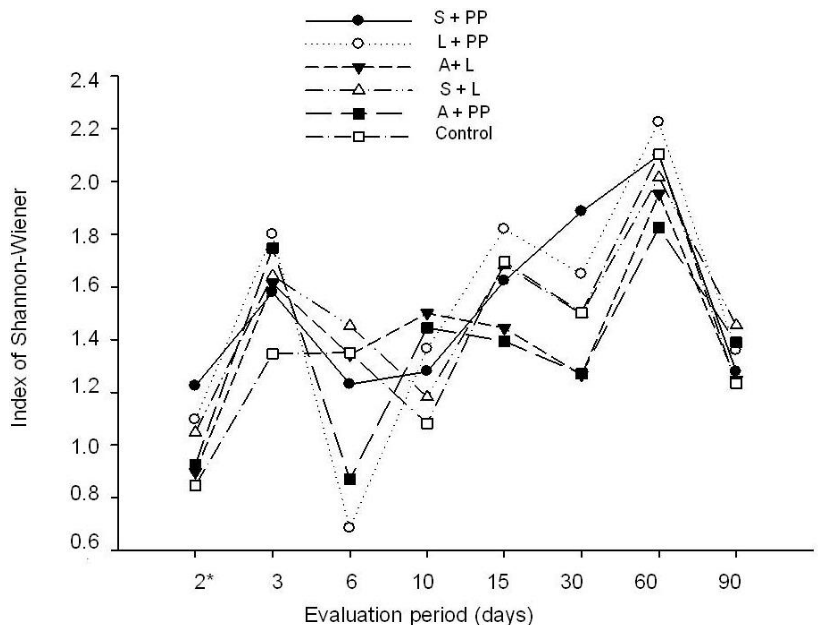

Figure 3. Shannon index of soil fauna in legume combinations in the alley cropping system in different periods of evaluation.

However, the other groups found in the alley cropping are not excluded, because they are also important in the maintenance of the internal regulation in the ecosystem energy flow. The macrofauna plays a key role in the ecosystem by occupying all trophic levels in the food chain from the soil, and to act directly and indirectly in primary production, by forming galleries that facilitate water infiltration, aeration and root penetration into the soil (Silva et al., 2007).

Due to their diversity and magnitude of their functions in the soil environment, some representatives of the macrofauna, such as spiders, beetles, termites, earthworms and ants are considered bioindicators since they are sensitive to environmental changes. Moreover, they are also helpful as disturbed environments restoration agents (Rocha et al., 2011; Ramos et al., 2015; Trifonova et al., 2015).

With respect to the Shannon - Wiener Diversity Index, the treatments showed different results between 6 and 15 dap. The highest value of the Shannon - Wiener Index was recorded at 60 dap for all treatments. This was reflected in a larger evenness in the same period, indicating a higher equitability of the abundance of each group, thus reducing the dominance of some groups such as mites and Collembola (Figures 3 and 4). Such an effect may have been caused by the decomposition rate of each treatment, because the arthropod preference varied with the plant material quality change (Resende et al., 2013).

There was no abrupt changes in the arthropod group diversity in the treatment S + PP (Figure 4), probably due to their higher C/N relationship and the polyphenol amount (Table 1), as few organisms are adapted to directly feed on materials under these conditions (Resende et al., 2013).

The cluster analysis based on the soil arthropod community structure revealed formation of two groups, one represented by the treatments A + PP, and A + L with similarity of approximately 46% (Figure 5). These two treatments had a similar amount of dry matter, besides the same C/N ratio at the beginning and end of the experiment. At the same time, the amount of weeds in these treatments was also lower. A study conducted in the same area showed that the treatments with *Acacia*

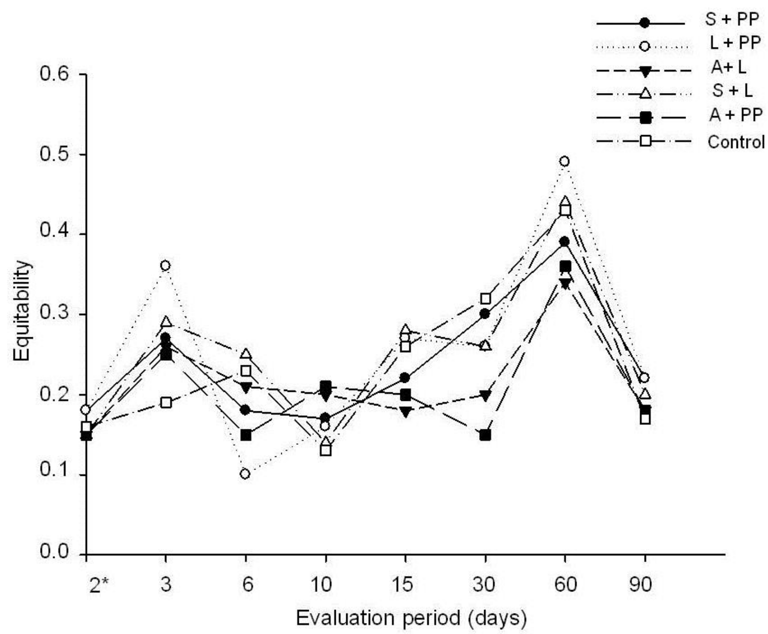

Figure 4. Equitability of soil fauna in legume combinations in the alley cropping system in different evaluation periods.

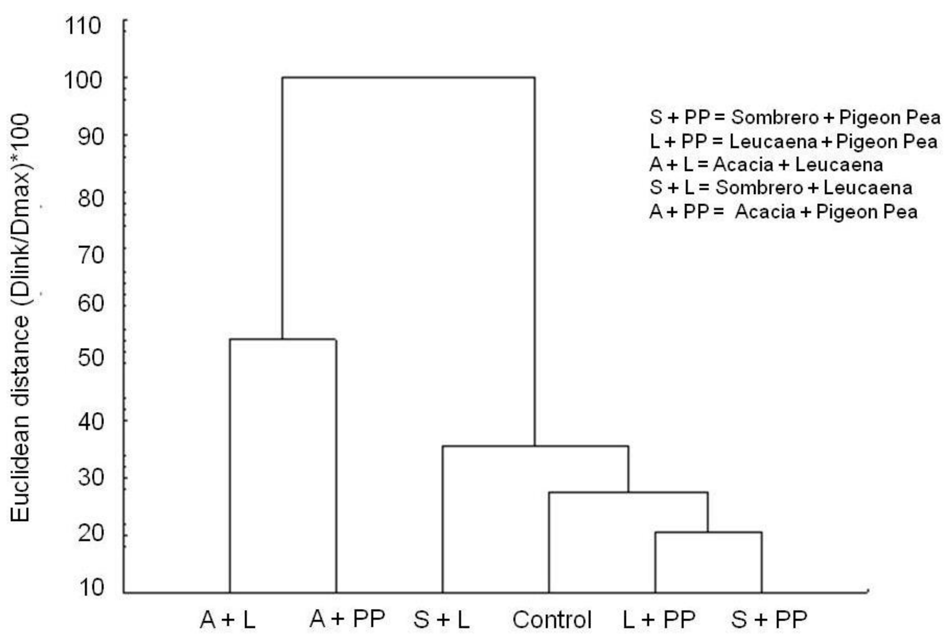

Figure 5. Similarity dendrogram of soil fauna based on Euclidean distance averages in legume combinations in the alley cropping system.

had a higher effect on the weed abundance due to the higher amount and durability of the waste (Moura et al., 2009).

The second group was formed by treatments L + PP, S + PP, S + L and control, and had approximately 64% similarity to each other. The treatments S + PP and L + PP showed 80% similarity, despite that the Sombrero is a legume with low residue quality. No soil fauna preference for the legume combination treatments was observed. However, it was observed that there was high activity in all treatments in search for better food quality and for protection from rain or as refuge by microhabitat complex, provided by the plant material with slower decomposition. This was observed not only for saprophagous groups, but also for various predators present in the system. According to Resende et al. (2013) the soil fauna varies during the plant residue decomposition process and species differ with respect to contrasting decomposition speeds; the polyphenol content is the feature that most affects this behavior.

Conclusion

The soil fauna under different vegetation covers is composed mainly of Aranae, Coleoptera, Diptera, Formicidae, Coleoptera larvae, mites and Collembola, and the latter two are the dominant groups. The soil fauna group richness varies with time of decomposition, with the greatest diversity recorded at 60 days after legume pruning due to the group homogeneity.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors are grateful to the Brazilian Agencies FAPEMA and CAPES for the financial support.

REFERENCES

Altieri MA, Silva EN, Nicholls CI (2003). O papel da biodiversidade no manejo de pragas. Ribeirão Preto: Holos P 226.
Anderson JM, Ingran JS (1993). Tropical biology and fertility, a handbook of methods. Wallingford, Oxfordshire: CAB International P. 221.
Baretta D, Baretta CRDM, Cardoso EJBN (2008). Análise multivariada de atributos microbiológicos e químicos do solo em florestas com *Araucaria angustifolia*. Rev. Bras. Ciênc. Solo 32:2683-2691.
Castellanos-Barliza J, León PJD (2011). Litter decomposition and nutrient release in *Acacia mangium* plantations established on degraded soils of Colombia. Rev. Biol. Trop. 59(1):113-128.
Cunha Neto FVD, Correia MEF, Pereira GHA, Pereira MG, Leles PSDS (2012). Soil fauna as an indicator of soil quality in forest stands, pasture and secondary forest. Rev. Bras. Ciênc. Solo 36(5):1407-1417.
Eisenhauer N, Bebler H, Engels C, Gleixner G, Habekost M, Milcu A, Partsch S, Sabais CW, Scherber C, Steinbeiss S, Weisser WW, Scheu S (2010). Plant diversity effects on soil microorganisms support the singular hypothesis. Ecology 91(2):485-496.
Embrapa (2013). Sistema Brasileiro de Classificação de Solos/Santos, HG et al. 3 ed. rev. ampl. Brasilia: Embrapa P 353.
Ferraz Junior ASL (2004). O cultivo em aléias como alternativa para a produção de alimentos na agricultura familiar do trópico úmido. In Moura EG (Ed.) Agroambientes de transição: entre o trópico úmido e o semi-árido do Brasil. São Luís: Universidade Estadual do Maranhão pp. 71-100.
Hoffmann RB, Nascimento MDSV, Diniz AA, Araújo LHA, Souto JS (2009). Diversidade da mesofauna edáfica como bioindicadora para o manejo do solo em Areia, Paraíba, Brasil. Rev. Caatinga 22(3):121-125.
Kaspari M (2004). Using the metabolic theory of ecology to predict global patterns of abundance. Ecology 85(7):1800-1802.
Mafongoya PL, Giller KE, Palm CA (1997). Decomposition and nitrogen release patterns of tree prunings and litter. Agrofor. Syst. 38(1):77-97.
Morselli TBGA (2007). Biologia do solo. Pelotas: UFPEL P145.
Monroy F, Aira M, Domínguez J (2011). Epigeic earthworms increase soil arthropod populations during first steps of decomposition of organic matter. Pedobiologia 54(2):93-99.
Moura EG, Aguiar ACF, Ferraz Junior ASL, Costa MG, Sousa JTR, Silva Junior EM, Gehring C (2009). Incidência de ervas daninhas e atributos do solo em um agrossistema da pré-amazônia, sob efeito da cobertura morta de diferentes combinações de leguminosas em aléias. Sci. Agrar. 10(1):7-14.
Nunes LAPL, Araújo Filho JA, Queiroz Menezes RÍ (2009). Diversidade da fauna edáfica em solos submetidos a diferentes sistemas de manejo no semi-árido nordestino. Sci. Agrar. 10(1):43-49.
Olson JS (1963). Energy storage and the balance of producers and decomposers in ecological systems. Ecology 44(2):322-331.
Ramos ASJC, Lemos RNS, Vale AMS, Batista MC, Moreira AA, Harada AY, Mesquita MLR (2015). Ant diversity in agro ecosystems and secondary forest. Afr. J. Agric. Res. 10(49):4449-4454.
Resende AS, Campello EFC, Silva GTA, Rodrigues KM, Oliveira WRD, Correia MEF (2013). Artropodes do solo durante o processo de decomposição da matéria orgánica. Agron. Colomb. 31(1):89-94.
Rocha JRM, Almeida JR, Lins GA, Durval A (2011). Insects as indicators of environmental changing and pollution: a review of appropriate species and their monitoring. Holos Environ. 10(2):250-262.
Santos GG, da Silveira PM, Marchão RL, Becquer T, Balbino LC (2008). Macrofauna edáfica associada a plantas de cobertura em plantio direto em um Latossolo Vermelho do Cerrado. Pesq. Agropec. Bras. 43(1):115-122.
Silva RF, Tomazi M, Pezarico CR, Aquino AM, Mercante FM (2007). Macrofauna invertebrada edáfica em cultivo de mandioca sob sistemas de cobertura do solo. Pes. Agrop. Bras. 42(6):865-871.
Silva CF, Martins MA, da Silva EMR, Pereira MG, Correia MEF (2013). Influência do Sistema de Plantio sobre Atributos Dendrométricos e Fauna Edáfica, em Área Degradada pela extração de argila. Rev. Bras. Ciênc. Solo 37(6):1742-1751.
Sparks DL, Page AL, Helmke PA, Loeppert RH (1996). Methods of Soil Analysis Part 3 - Chemical methods. SSSA Book Ser. 5.3. SSSA, ASA, Madison, WI.
Tedesco MJ (1982). Extração simultânea de N, P, K, Ca e Mg em tecido de plantas por digestão com H_2O_2-H_2SO_4. Porto Alegre: UFRGS P.50.
Trifonova TA, Buyvolova AY, Buyvolov YA, Bykova EP (2015). Seasonal variation of soil macrofauna in forest ecosystems of the Prioksko-Terrasnyi Biosphere Reserve. Moscow Univ. Soil Sci. Bull. 70(4):187-192.
Vasconcelos MCCA, Silva AFA, Lima RS (2012). Cultivo em Aléias: uma alternativa para pequenos agricultores. Agropec. Cient. Semi-árido 8(3):18-21.
Wang S, Ruan H, Han Y (2010). Effects of microclimate, litter type, and mesh size on leaf litter decomposition along an elevation gradient in the Wuyi Mountains, China. Ecol. Res. 25(6):1113-1120.