DOI: 10.5433/1679-0359.2012v33n1p183

Dynamic of epigeous macrofauna under organic soil management in the Brazilian semi-arid region

Dinâmica da macrofauna epígea sob manejo orgânico do solo no semi-árido brasileiro

Márcio Sampaio Pimentel[1*]; Rubens Silva Carvalho[2]; Daniela Pionório Vilaronga[1]; Lindete Míria Vieira Martins[2]; Adriano Victor Lopes da Silva[1]

Abstract

Soil macrofauna is responsible for soil fertility through cycling of nutrients, tillage and fragmentation of organic matter, as well as through the association between groups of fauna with conserved and/or degraded pedoenvironments. Nevertheless, under the conditions of the Brazilian semi-arid region, there is little information about this resource. The objective of this study was to evaluate the epigeous macrofauna in successive cropping using previous green manure and subsequent planting of melon (*Cucumis melo* L.) in Juazeiro county, Bahia, Brazil. Sampling dates were undertaken in November 2007 and February, April and July 2008, using traps containing 4 % formaldehyde for seven days in plots of 64 m^2. Results obtained indicate that there is no difference among the treatments with mixed cover crops, and epigeous macrofauna is influenced by the time of collection. Diversity and uniformity are inversely correlated with total density of epigeous macrofauna. Diversification of plant species favors the increase of diversity and uniformity of epigeous macrofauna. Formicidae, followed by Isopoda, Coleoptera and Oligochaeta are the groups of fauna most numerous in the areas.
Key words: Caatinga, soil fauna, soil biology, green manure, mixed cover crops

Resumo

A macrofauna do solo é responsável pela melhoria da fertilidade do solo através da ciclagem de nutrientes, revolvimento e fragmentação da matéria orgânica, como também, pela associação entre grupos de fauna com pedoambientes conservados e/ou degradados. No entanto, nas condições de semi-árido brasileiro pouca informação se tem a respeito deste recurso. Neste sentido, na região do sub-médio do Rio São Francisco, pólo de desenvolvimento da agricultura irrigada objetivou-se avaliar a macrofauna epígea em sucessão cultural utilizando prévia adubação verde e subseqüente plantio de melão (*Cucumis melo* L.). As coletas foram realizadas em novembro de 2007 e fevereiro, abril e julho de 2008 no município de Juazeiro, BA, utilizando armadilhas contendo formol 4 % durante sete dias em parcelas de 64 m^2. Os resultados obtidos indicam que não há diferença entre os tratamentos com coquetéis vegetais e que a macrofauna epígea é influenciada pela época de coleta. A diversidade e a uniformidade correlacionam-se inversamente com a densidade total da macrofauna epígea. A diversificação de espécies vegetais favorece o aumento da diversidade e uniformidade da macrofauna epígea e que Formicidae, seguido por Isopoda, Coleóptera e Oligochaeta são os grupos de fauna mais encontrados nos ambientes avaliados.
Palavras-chave: Caatinga, fauna do solo, biologia do solo, adubação verde, coquetel vegetal

[1] Profs. de Agronomia e Bolsista de Iniciação Científica Fapesb/PIBIC; Universidade Federal do Vale do São Francisco, Rod. BR 407 Km 12 Lote 543 Projeto de Irrigação Senador Nilo Coelho, s/nº C1, 56.300-000. Petrolina, PE. E-mail: marcio.pimentel@univasf.edu.br; adriano.victor@univasf.edu.br; danipionorio_zootecnia@hotmail.com

[2] Mestrando em Agronomia e Profª Adjunta da Universidade do Estado da Bahia; Deptº de Tecnologia e Ciências Sociais, Av. Edgard Chastinet S/N São Geraldo; 48900-000; Juazeiro, BA. E-mail: rusilca@ig.com.br; mirialind@yahoo.com.br

[*] Corresponding author

Recebido para publicação 18/10/10 Aprovado em 17/11/11

Introduction

Organic soil management represents a promising alternative for sustainable food production (MERLIM et al., 2005) and the conservation of existing natural resources, like soil macrofauna, with legume species being greatly used due to biological fixing of atmospheric nitrogen and production of a large quantity of plant biomass (PAULO et al., 2006) which is incorporated into the soil, promoting better utilization of soil mineral nutrients, water retention and reduced thermal amplitude of the soil surface. The addition of organic residues in crop systems is a positive factor for soil biology through provision of food and better abiotic conditions for organisms (BARETTA et al., 2003).

Soil macrofauna is composed of organisms with length greater than 10 mm, visible to the naked eye and responsible for some soil activities, such as fragmentation of organic residues, mixture of mineral and organic particles, redistribution of organic matter and production of fecal pellets (HENDRIX et al., 1990; BARETTA et al., 2007). The concept of biodiversity is understood as the number and richness of associated species; occasionally this concept is extended to the richness of varieties, cultivars or genetic expressions and microorganisms (BÜCHS, 2003). Soil biodiversity is responsible for diverse environmental services, such as providing stability against soil stresses and disturbances caused by man (BRUSSAARD, RUITER; BROWN, 2007). Thus, the existence of possible associations between soil fauna groups and types of pedoenvironments (RUF et al., 2003) will contribute to better understanding of the relationship between biodiversity and environmental services.

In Brazil, studies regarding soil fauna are relatively recent and include organisms and their activities in pedological processes, having been used as an indicator of agricultural practices through time (GIRACCA et al., 2008). Portilho et al. (2011) observed that the highest diversity and group richness of epigeic invertebrate fauna were observed in the cane sugar crop with the maintenance of the surface residues. In this sense, macrofauna can function as an indicator of environmental changes since they are sensitive to the type of soil cover and the availability of energy in the system (TIAN, BRUSSARD; KANG, 1999).

Some studies regarding soil macrofauna are being undertaken in semi-arid regions throughout the world (OUÉDRAOGO, MANDO; BRUSSARD, 2004; 2006). Nevertheless, in relation to the Brazilian semi-arid conditions, studies related to their potential are practically null. This bioma has been little investigated and is quite threatened (JANZEN, 1997). In the São Francisco River Valley region in the Petrolina, Pernambuco and Juazeiro, Bahia areas in Brazil, a highly technified agriculture has been developed using fruit cropping with strong commercial insertion in domestic and foreign markets due to the favorable ecological conditions and availability of area (PASSOS et al., 2004). In spite of the progress associated with irrigated fruit cropping, little or no value has been given to biodiversity and particularly to soil macrofauna in agricultural systems.

Therefore, considering the importance of invertebrate soil macrofauna in the functioning of the ecosystem; and since they occupy diverse trophic levels within the soil food chain and affect primary production in a direct and indirect manner (SILVA et al., 2006), their quantification and identification is important for aiding in a more precise diagnosis regarding soil quality management, as well as for increasing knowledge regarding biodiversity in the Brazilian semi-arid region. The objective of this study was to investigate epigeous macrofauna in successive cropping using previous green manure as a means of incorporating organic residues in pre-cultivation of the melon crop (*Cucumis melo* L.).

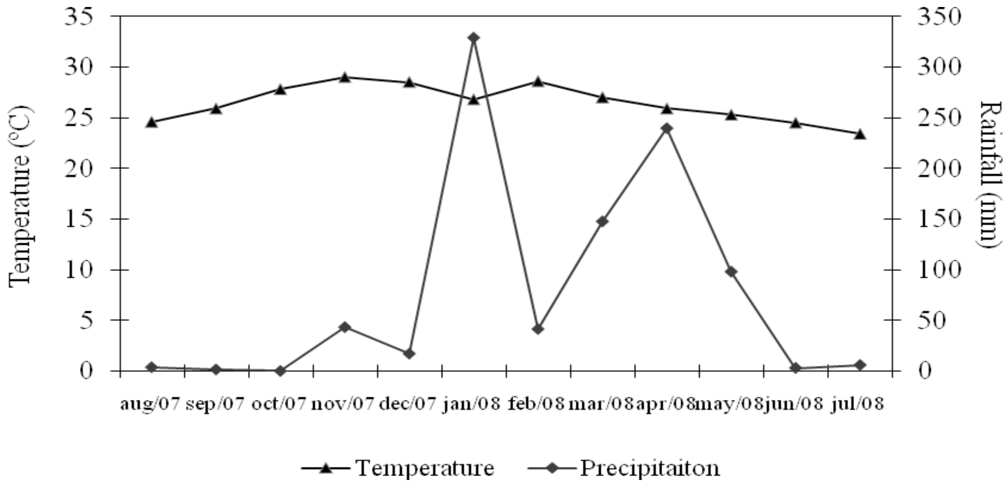
Material and Methods

In an area of the experimental field of the State University of Bahia (Universidade do Estado da Bahia), Technology and Social Science Department

(DTCS), Campus III located in Juazeiro, Bahia, Brazil, a study of the epigeous macrofauna in soil submitted to a green manure-melon succession was developed in the year 2007-2008.

The region is situated at 9º25' latitude south and 40º29' longitude east, with an altitude of 366m. According to the Köeppen climatic classification, the climate is BSh, characterized by rain distributed from November to March between 250 and 500mm and a dry period in the winter, and annual average temperature of 24.2 ºC, with an average maximum of 29.6 ºC and minimum of 20.3 ºC. The highest temperatures are distributed in the months of January and February, while the lowest monthly averages occur in the months of June and July (Figure 1).

Figure 1. Temperature and rainfall distribution in Juazeiro, BA, Brazil during the period from August 2007 up to July 2008. Arrows represent soil sampling date (November 2007, February, April and July 2008).



Source: Embrapa CPATSA.

Soil preparation was made through deep subsoiling, plowing, disking and delimitations in plots of 64 m^2 (8 m x 8 m). The soil is a Fluvic Neosol (EMBRAPA, 1999) with clay-sandy loam texture with 48.9 % clay, 29.0 % sand and 22.1 % silt.

The green manure was planted on December 20, 2007 by the broadcast method, undertaking mechanized harvest on April 15, 2008 and the planting of melon (*Cucumis melo* L.) AF-684 hybrid was then performed. The plots were disposed contiguous and spacing used for the melon was 0.40 m between plants and 2.0 m between rows, totaling 12,500 thousand plants ha^{-1} grown under a drip irrigation system in association with the species selected for composition of the cover crop mix, except for the conventional crop treatment.

The experimental design was randomized blocks with five treatments (four cover crop mix treatments and control) and four replications. The species that composed the cover crop mix treatments were: T1: Control. T2 and T3: *Zea mays* L., *Pennisetum glaucum*, *Sorghum bicolor* L., *Mucuna nivea*, *Crotalaria spectabilis*, *Leucaeana leucocephala*, *Canavalia ensiformis*. T4 and T5: *Z. mays* L., *M. nivea*, *C. ensiformis*, *L. leucocephala*, *C. spectabilis*, *S. bicolor* L., *Helianthus annuus*, *Ricinus communis* L., *Vigna unguiculata* L., *Cajanus cajan*, *Dolichos lab lab*, *Crotalaria juncea*, *Mucuna aterrina*. In treatments T3 and T5, the legume seeds were inoculated with *Rhizobium* genus.

Samples of epigeous macrofauna were taken in November 2007 (before the cover crop mix treatment), February (during cover crop mix treatment), April (after cover crop mix treatment and during melon cropping) and July 2008 (after melon harvest), using the method of Pitfall Trapping, adapted by Greenslade in 1964 (MOLDENKE, 1994), which is composed of a container buried until its hollowed end is at the soil surface level. Within these containers was placed formaldehyde at 4 %. Four pitfall traps, collected randomized, were used in each plot for seven days, with sampling dates of all the fauna being made on the last day and conserved in alcohol at 70 %, for later identification at the level of large taxonomic groups and counting under a stereoscopic microscope. Communities were characterized based on the parameters described as follows: a) density, number of individuals per trap/day, b) richness, number of groups, c) uniformity, distribution of individuals by the total group and d) diversity (Shannon diversity index). The Shannon diversity index was obtained by the ratio ($H = -\Sigma\, pi \log pi$), in which: $pi = ni/N$; ni is the density of each group; N is the total number of groups, according to Magurran (1988).

The dates were submitted to the Kolmogorov-Smirnov test to verify normal distribution, and indicated normal distribution. Analysis of variance was performed and it was observed that all the attributes did not present a significant difference for cover crop mix treatments. However, a significant difference was observed for the sampling date, and a means comparison test, the Tukey test, was applied, which serves as a complement for the study of analysis of variance to differentiate the sampling date. A correlation analysis was made among the ecological indexes, adopting values above 70 % and considering them as strongly correlated. The multivariate techniques of principal component analysis (PCA) and grouping analysis were used to better visualize these differences between the means of the attributes in relation to the areas. In the case of PCA, the data were standardized using self-scheduling so that each piece of data has the same weight. All analyses were made on the statistical program R, version 2.9.1.

Results and Discussion

Significant differences were not observed among the treatments used; however, density, richness, diversity and uniformity of epigeous macrofauna differed in terms of the collection time (Table 1). When the cover crop mix was introduced (Feb/08), an improvement in the uniformity of epigeous macrofauna was observed; in other words, the distribution of the groups by total density of individuals became more balanced, while diversity was also greater in Feb/08. In April/08, a period after the cover crop mix, the total density of epigeous macrofauna showed a significant decline and, in contrast, the mean richness was significantly greater in the same period.

Table 1. Mean values of density, richness, diversity and uniformity of epigeous macrofauna in the soil sampling date undertaken throughout the experiment in the Brazilian semi-arid region.

Sampling date	Density	Richness	Diversity	Uniformity
November 07	110.54 a	0.36 c	10.95 ab	0.35 c
February 08	84.20 a	0.48 b	12.00 a	0.44 bc
April 08	20.85 b	0.66 a	9.50 b	0.70 a
July 08	108.22 a	0.46 bc	9.95 b	0.46 b

Averages followed by different letters in the column differ significantly among themselves by the Tukey test ($P<0.05$).
Source: Elaboration of the authors.

Results indicate that with the use of the cover crop mix, there was a significant change in the ecological indexes; the adoption of different plant species as cover crops favored epigeous macrofauna through the increase in diversity and uniformity.

The correlations above 0.70, from 0.50 to 0.70, and below 0.50 were classified as strong, moderate and weak, respectively. The greatest density of individuals did not necessarily result in greater diversity and uniformity (Table 2); on the contrary, it may be observed that density presented opposing behavior (negative correlation) to diversity and uniformity, such that between these last two, the greatest and strongest correlation (0.87) was obtained. With regards to richness, all the correlations related to this index were low (below 0.35) since values less than 0.50 are considered as null correlations (CAROMANO et al., 2003).

Table 2. Correlation matrix among density, richness, diversity and uniformity evaluated during green manure – melon successive cropping in Juazeiro county, BA, Brazil.

Indexes	Density	Richness	Diversity	Uniformity
Density	1.00	0.30	-0.47	-0.58
Richness	-	1.00	0.03	-0.35
Diversity	-	-	1.00	0.87
Uniformity	-	-	-	1.00

Source: Elaboration of the authors.

In regard to the medial number of individuals per trap day, ants were the individuals collected that were most present in the areas (1062,57), followed by Isopods (269,62), Coleoptera (258,21), Oligochaeta (167,35), Araneae (59,52), Diptera (35,98), Orthoptera (35,70), Isoptera (25,62) and Blattodea (21,06) (Table 3). These results suggest that the conditions which favored diversity and uniformity were adverse to the density of epigeous macrofauna; in other words, the increase in density was associated with the presence of one specific group (ants).

Results indicate that in the general average, Formicidae, Isopodas, Coleoptera and Oligochaeta were the most favored groups during the period evaluated. In relation to Oligochaeta, it is possible to perceive that there was a quantitative increase in its density in the period from Feb/08 in treatments T4 and T5, while in T2 and T3, the same situation did not occur. This difference may possibly be the result of some effect of the species used in T4 and T5 (Sunflowers, Castor bean, Cowpea, Pigeon pea, Lablab bean, *Crotalaria juncea* and *Mucuna aterrina*) and not present in T2 and T3; i.e., better quality organic matter, produced by legumes, favors the development of a richer community.

Special attention must be given to the Isoptera (termites), which, together with Formicidae and Oligochaeta, are known as the engineers of ecosystems for performing functions that lead to the creation of biogenic structures that modify the physical properties of soils, as well as making resources available to other organisms (WOLTERS, 2000). In this study, low populations of termites were observed, which may be associated with the quality of the incorporated organic matter (low C/N) because, according to Lavelle and Spain (2001), there is an association between Isoptera and organic matter with a high C/N ratio.

Table 3. Medial number of individuals per trap day^{-1} for main groups of epigeous macrofauna in November 2007 (1), February (2), April (3) and July 2008 (4) in soil subjected to five treatments with different compositions of green manures in the Bahian semi-arid region.

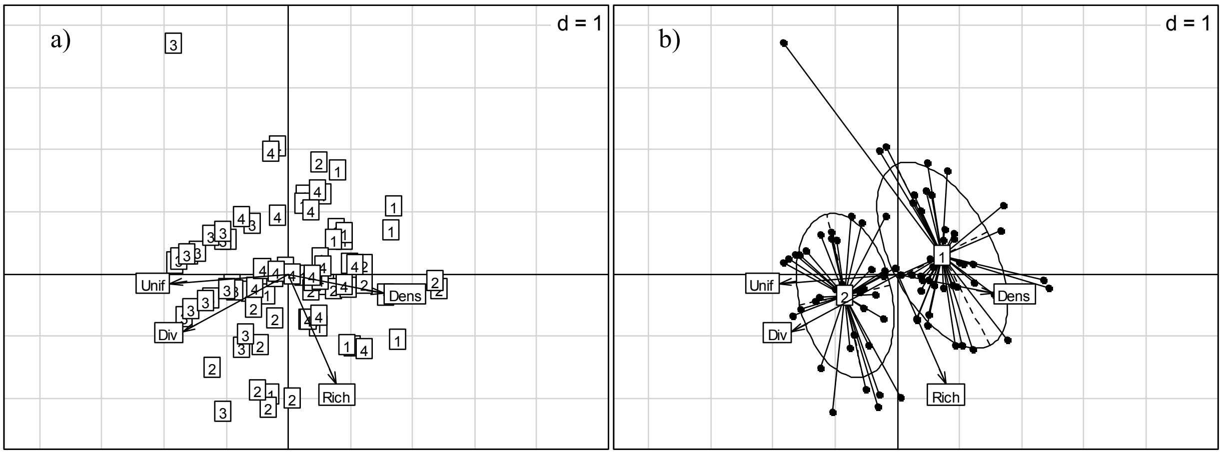
Treat	Sampling date	Formicidae	Isopoda	Coleoptera	Oligochaeta	Araneae	Diptera	Orthoptera	Isoptera	Blattodea	Others
		number of individuals per trap day^{-1}									
1		79,27	3,52	8,71	0,07	4,30	0,39	0,68	0,07	0,57	2.42
2		78,02	8,47	6,67	0,00	3,56	0,08	0,28	0,00	1,48	1.44
3	1	78,22	7,52	7,11	0,00	3,66	0,10	0,20	0,03	1,25	1.92
4		67,46	17,03	8,87	0,00	2,60	0,13	0,34	0,00	2,09	1.48
5		78,30	7,57	7,78	0,00	2,58	0,12	0,55	0,09	1,03	1.98
1		40,09	3,04	25,55	17,46	1,28	4,38	0,97	1,70	0,30	5.23
2		72,48	1,68	8,07	15,56	0,64	0,25	0,00	0,04	0,14	1.14
3	2	49,03	3,86	13,94	18,54	1,15	5,29	0,69	0,28	0,37	6.85
4		23,49	2,73	10,65	54,05	0,63	2,46	0,36	0,18	0,36	5.10
5		20,53	9,31	5,59	60,39	0,42	0,14	0,46	0,07	0,28	2.81
1		37,65	3,70	24,07	0,62	6,48	6,79	13,27	0,00	1,85	5.56
2		44,81	5,97	20,95	0,14	3,33	1,94	4,30	14,85	1,80	1.90
3	3	32,16	19,86	24,78	0,35	2,99	3,69	4,04	2,81	5,10	4.24
4		32,85	3,77	39,32	0,18	2,87	6,64	5,92	0,18	1,44	6.82
5		41,41	12,79	27,32	0,00	1,74	3,49	1,89	5,23	1,31	4.83
1		63,84	26,66	3,80	0,00	2,91	0,00	0,30	0,00	0,30	2.20
2		60,37	29,07	2,23	0,00	5,46	0,03	0,25	0,03	0,39	2.18
3	4	53,52	33,64	3,24	0,00	6,96	0,05	0,43	0,00	0,34	1.82
4		48,61	40,75	4,45	0,00	3,56	0,00	0,25	0,00	0,32	2.06
5		60,45	28,68	5,12	0,00	2,40	0,00	0,52	0,07	0,35	2.40
Sum		1062,57	269,62	258,21	167,35	59,52	35,98	35,70	25,62	21,06	64,39

T1: Control. T2 and T3: *Zea mays* L., *Pennisetum glaucum*, *Sorghum bicolor* L., *Mucuna nivea*, *Crotalaria spectabilis*, *Leucaeana leucocephala*, *Canavalia ensiformis*. T4 and T5: *Z. mays* L., *M. nivea*, *C. ensiformis*, *L. leucocephala*, *C. spectabilis*, *S. bicolor* L., *Helianthus annuus*, *Ricinus communis* L., *Vigna unguiculata* L., *Cajanus cajan*, *Dolichos lab lab*, *Crotalaria juncea*, *Mucuna aterrina*. Others: Chilopoda, Dermaptera, Diplopoda, Diplura, Gastropoda, Hemiptera, Homoptera, Hymenoptera, Lepidoptera, Mantodea, Opilionida, Phasmatodea, Protura, Pseudoscorpionida, Psocoptera, Scorpionida, Symphila, Trichoptera, Thysanura.

Source: Elaboration of the authors.

Principal component analysis (PCA) was used to verify the dispersion of density, richness, diversity, uniformity and the groups of epigeous macrofauna (arrows) in terms of the time period (numbers), with arrow length being proportional to the correlation of the characteristic with the axes and their importance in the explanation of the variance projected on each axis of analysis (Figures 2a and 2b), whose percentage of explanation of the variability from the original data was 92 % and 67 % in the two and four principal components respectively. Analysis of grouping allowed the detection of groupings to be undertaken, explaining 92 % of the total variance from the first two components (Figure 2b).

Figure 2. Principal component analysis among density, richness, diversity and uniformity in November 2007 (1), February (2), April (3) and July 2008 (4) (a) and analysis of grouping among density, richness, diversity and uniformity in November 2007 and July 2008 (1) and in February and April 2008 (2) (b). In both cases, the percentage of explanation of the variability of the original data from the first two principal components was 92 %.



Source: Elaboration of the authors.

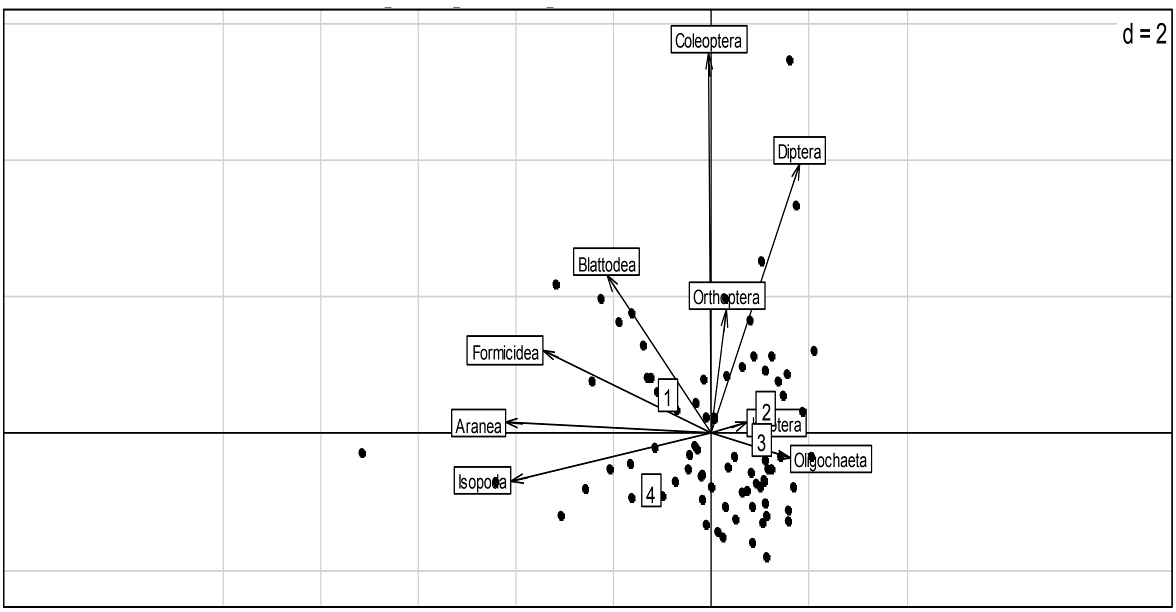
It is possible to observe the formation of two distinct groupings: uniformity with diversity, and density with richness, which occurred in the periods of Feb/08 and Apr/08 and of Nov/07 and Jul/08, respectively (Figure 2b). It is relevant to observe that the sampling dates of Feb/08 and Apr/08 were marked by greater mean rainfall, compared to Nov/07 and Jul/08, which were drier periods (Figure 1). Menezes et al. (2009) evaluating the soil macrofauna in successive phases of Semidecidual Seasonal Forest and mixed pasture, observed that Formicidae and Oligochaeta were dominant, such that the latter declined in the dry period, the same trend observed in this study. So as to ratify these results, the existence of strong correlations (above 0.7) were observed for density (0.77), diversity (-0.85) and uniformity (-0.93) with Y1, whereas for Y2 the richness variable was that which most contributed to explanation of the analysis (-0.89).

Considering that Nov/07 and Jul/08 refer to the pre-cover crop mix period and after the melon harvest, while February and April 2008 refer to the periods during green manure and during melon growing, respectively, the results obtained in Table 1 are corroborated; in other words, the cover crop mix exercised a positive effect on diversity and uniformity of epigeous macrofauna, while in Nov/07 and Jul/08, it favored the increase in density, especially of ants. The abundance of ants has been observed in some studies, such as Lima et al. (2007), who, upon evaluating the soil macrofauna in an organic and conventional system, observed that in the organic growing system, the most present groups were ants and termites, followed by earthworms and beetles. Meanwhile, for Dias et al. (2006), the use of legumes stimulates the increase of density, richness and diversity of soil fauna, mainly in Oligochaeta, Coleoptera, Araneae and Formicidae.

According to Souto et al. (2008), the more effective presence of the herbaceous and bush stratum increased the food supply, favoring soil macrofauna, just as in the environments that received a plant mix. In a similar study, Silva et al. (2006), evaluating different soil management systems, observed that the no-till system was that which presented the greatest diversity of soil macrofauna groups, while for Menezes et al. (2009), the soil macrofauna community showed sensitivity to the increase in diversity of plants, and seasonal aspects presented an effect on density, spatial distribution and average richness, not altering the total diversity of fauna in the different systems. Therefore, these results reinforce the fact that plant diversity and soil cover favor the increase of soil macrofauna.

In Figure 3, the PCA was undertaken only for the groups that presented total density above 1 % during the period (Araneae, Blattodea, Coleoptera, Diptera, Formicidae, Isopoda, Isoptera, Oligochaeta and Orthoptera). It is possible to perceive that spiders were the group with greatest correlation with Nov/07 and Jul/08 (-0.86) in Y1; the contributions of Isopods (-0.51) and ants (-0.48) were of lesser intensity. On the other hand, in spite of the low correlations, a tendency of greater occurrence of the Diptera and Oligochaeta groups is observed in the period of Feb/08 and Apr/08. The Coleoptera group presented a strong correlation to Y2 (0.76); however, in accordance with its position in the figure, it may be observed that this group was distributed in a homogeneous way throughout the time periods.

Figure 3. Principal component analysis of the principal groups that presented occurrences greater than 1 % throughout the period evaluated found in November 2007 (1), February (2), April (3) and July 2008 (4), whose percentage of explanation of the variability of the original data was 67 % from the first four principal components.



Source: Elaboration of the authors.

Conclusions

There is no difference among the treatments with cover plant mixes, with epigeous macrofauna being influenced by the period of sample collection;

Diversity and uniformity are inversely correlated with the total density of epigeous macrofauna;

Diversification of the plant species favors the increase of diversity and uniformity of epigeous macrofauna;

Formicidae, followed by Isopoda, Coleoptera and Oligochaeta are the fauna groups most numerous in the environments evaluated.

Acknowledgements

We would like to thank FAPESB for financial support.

References

BARETTA, D.; BROWN, G. G.; JAMES, S. W.; CARDOSO, E. J. B. N. Earthworm populations sampled using collection methods in Atlantic Forests with Araucaria angustifolia. *Scientia Agricola*, Piracicaba, v. 64, n. 4, p. 384-392, 2007.

BARETTA, D.; SANTOS, J. C. P.; MAFRA, A. L.; WILDNER, L. P.; MIQUELLUTI, D. J. Fauna edáfica avaliada por armadilhas de catação manual afetada pelo manejo do solo na região oeste catarinense. *Revista de Ciências Agroveterinárias*, Lages, v. 2, n. 2, p. 97-106, 2003.

BRUSSAARD, L.; RUITER, P. C. de; BROWN, G. G. Soil biodiversity for agricultural sustainability. *Agriculture, Ecosystems and Environment*, Amsterdam, v. 121, n. 3, p. 233-244, 2007.

BÜCHS, W. Biodiversity and agri-environmental indicators general scope and skills with special reference to the habitat level. *Agriculture, Ecosystems and Environment*, Amsterdam, v. 98, n. 1, p. 35-78, 2003.

CAROMANO, F. A.; NIITSUMA, L. Y.; VAINZOF, M.; ZATZ, M. Correlação entre o tempo de realização de diferentes atividades físicas por portadores de distrofia muscular de Duchenne. *Revista Terapia Ocupacional Universitária*, São Paulo, v. 14, n. 3, p. 133-140, 2003.

DIAS, P. F.; SOUTO, S. M.; CORREIA, M. E. F.; ROCHA, G. P.; MOREIRA, J. F.; RODRIGUES, K. de M.; FRANCO, A. A. Árvores fixadoras de nitrogênio e macrofauna do solo em pastagem de híbrido de Digitaria. *Pesquisa Agropecuária Brasileira*, Brasília, v. 41, n. 6, p. 1015-1021, 2006.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA – EMBRAPA. Centro Nacional de Pesquisa de Solos (Rio de Janeiro, RJ). Sistema brasileiro de classificação de solos. Brasília: Embrapa-SPI, Embrapa-CNPS, 1999. 412 p.

GIRACCA, E. M. N.; ANTONIOLLI, Z. I.; STEFFEN, R. B.; STEFFEN, G. P. K.; SCHIRMER, G. K.; ELTZ, F. L. F. Influência da aplicação de calcário na população da meso e macrofauna do solo sob sistema plantio direto. *Ciência e Agrotecnologia*, Lavras, v. 32, n. 6, p. 1794-1801, 2008.

HENDRIX, P. F.; CROSSLEY JUNIOR, D. A.; BLAIR, J. M.; COLEMAN, D. C. Soil biota as components of sustainable agroecosystems. In: EDWARDS, C. A.; LAL, R.; MADDEN, P.; MILLER, R. H.; HOUSE, G. (Ed.). *Sustainable agricultural systems*. Ankey, Iowa: Soil and Water Conservation Society, 1990. p. 637-654.

JANZEN, D. H. Florestas tropicais secas: o mais ameaçado dos ecossistemas tropicais. In: WILSON, E. O. (Ed.). *Biodiversidade*. Nova Fronteira, 1997. cap. 14, p. 166-176.

LAVELLE, P.; SPAIN, A. V. *Soil ecology*. Dordrecht: Kluwer Academic Publishers, 2001. 654 p.

LIMA, H. V. de; LIVEIRA, T. S. de; OLIVEIRA, M. M. de; MENDONÇA, E. de S.; LIMA, P. J. B. F. Indicadores de qualidade do solo em sistemas de cultivo orgânico e convencional no semi-árido cearense. *Revista Brasileira de Ciência do Solo*, Campinas, v. 31, n. 5, p. 1085-1098, 2007.

MAGURRAN, A. E. *Ecological diversity and its measurement*. New Jersey: Princeton University Press, 1988. 179 p.

MENEZES, C. E. G.; CORREIA, M. E. F.; PEREIRA, M. G.; BATISTA, I.; RODRIGUES, K. de M.; COUTO, W. H.; ANJOS, L. H. C. dos; OLIVEIRA, I. P. de. Macrofauna edáfica em estádios sucessionais de Floresta Estacional Semidecidual e pastagem mista em Pinheiral (RJ). *Revista Brasileira de Ciências do Solo*, Campinas, v. 33, n. 6, p. 1647-1656, 2009.

MERLIM, A. de O.; GUERRA, J. G. M.; JUNQUEIRA, R. M.; AQUINO, A. M. de. Soil macrofauna in cover crops of figs grown under organic management. *Scientia Agricola*, Piracicaba, v. 62, n. 1, p. 57-61, 2005.

MOLDENKE, A. R. Arthropods. In: WEAVER, R. W.; ANGLE, S.; BOTTOMLEY, P.; BEZDICEK, D.; SMITH, S.; TABATABAI, A.; WOLLUM, A. (Ed.). *Methods of soil analysis:* microbiological and biochemical properties. Madison: SSSA, 1994. Part 2. p. 517-542.

OUÉDRAOGO, E.; MANDO, A.; BRUSSARD, L. Soil macrofauna affect crop nitrogen and water use efficiencies in semi-arid West Africa. *European Journal of Soil Biology*, Montrouge, v. 42, n. 1, p. 275-277, 2006.

______. Soil macrofaunal-mediated organic resource disappearance in semi-arid West Africa Elisée. *Applied Soil Ecology*, Amsterdam, v. 27, n. 3, p. 259-267, 2004.

PASSOS, O. S.; SANTOS FILHO, H. P.; CUNHA SOBRINHO, A. P. da; COELHO, Y da S.; SOARES FILHO, W. dos S.; NASCIMENTO, A. S. do; MAGALHÃES, A. F. de J.; SOUZA, L. D.; RITZINGER, C. H. S. P. *Certificação e diversificação da citricultura do nordeste brasileiro.* Embrapa Cruz das Almas, 2004. 7 p. (Comunicado técnico, 101).

PAULO, E. M.; BERTON, R. S.; CAVICHIOLI, J. C.; BULISANI, E. A.; KASAI, F. S. Produtividade do cafeeiro mundo novo enxertado e submetido à adubação verde antes e após recepa da lavoura. *Bragantia*, Campinas, v. 65, n. 1, p. 115-120, 2006.

PORTILHO, I. I. R.; BORGES, C. D.; COSTA, A. R.; SALTON, J. C.; MERCANTE, F. M. Resíduos da cultura da cana-de-açúcar e seus efeitos sobre a fauna invertebrada epigeica. *Semina: Ciências Agrárias*, Londrina, v. 32, n. 3, p. 959-970, 2011.

RUF, A.; BECK, L.; DREHER, P.; HUND-RINKE, K.; RÖMBKE, J.; SPELDA, J. A biological classification concept for the assessment of soil quality: biological soil classification scheme (BBSK). *Agriculture, Ecosystems and Environment*, Amsterdam, v. 98, n. 1-3, p. 263-271, 2003.

SILVA, R. F. da; AQUINO, A. M. de; MERCANTE, F. M.; GUIMARÃES, M de F. Macrofauna invertebrada do solo sob diferentes sistemas de produção em Latossolo da Região do Cerrado. *Pesquisa Agropecuária Brasileira*, Brasília, v. 41, n. 4, p. 697-704, 2006.

SOUTO, P. C.; SOUTO, J. S.; MIRANDA, J. R.P. de; SANTOS, R.V. dos; ALVES, A. R. Comunidade microbiana e mesofauna edáficas em solo sob caatinga no semi-árido da Paraíba. *Revista Brasileira de Ciências do Solo*, Campinas, v. 32, n. 32, p. 151-160, 2008.

TIAN, G.; BRUSSARD, L.; KANG, B. T. The role of plant residue with different chemical compositions in sustaining maize production in a subhumid tropical environment. In: BADEJO, M. A.; TOGUN, A. O. (Ed.). *Strategies and tactics of sustainable agriculture in the tropics*. Ibadan: College Press; Surulere: Emproct Consultants, 1999. v. 1, p. 68-84.

WOLTERS, V. Invertebrate control of soil organic matter stability. *Biology and fertility of Soils*, Berlin, v. 31, n. 1, p. 1-19, 2000.