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Soil fauna under eucalypt stands of different ages in the Savanna of Piauí

Fauna do solo sob povoamentos de eucalipto em diferentes idades no Cerrado do Piauí

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Abstract

The reforestation with eucalyptus has increased significantly in the Brazilian Savanah and it can promote changes on soil biological properties, mainly soil fauna. Thus, the aim of this study was to evaluate the composition of soil fauna in areas with *Eucalyptus* plantations of different ages compared with native savanna. The study was conducted in Eucalytptus plantations aged one, two, three and four years and area with native forest was taken as reference. Soil fauna was collected in the dry and rainy season to evaluate the number of individuals from different taxonomic groups, richness, uniformity and diversity. The highest number of soil fauna was found in eucalyptus plantations with one year old at both seasons. However, the richness did not differ between seasons. In areas where with eucalyptus plantations with one and two years old showed 90% of individuals represented by Coleoptera and Formicidae, which contributed for decreasing in fauna uniformity. The implantation of *Eucalyptus* early reduced the diversity and uniformity of soil fauna; however, there was a recovery of this biological attribute after two years of reforestation.

Additional keywords: native forest; seasonality; species diversity.

Resumo

O plantio de eucalipto tem aumentado significativamente em áreas anteriormente ocupadas por vegetação de Cerrados, e isto pode promover mudanças nos atributos biológicos do solo, principalmente sobre a fauna edáfica. Desta forma, o objetivo do trabalho foi avaliar a composição da fauna do solo em povoamentos de eucalipto do solo com diferentes idades, em comparação com remanescentes de vegetação de Cerrados. O estudo foi realizado em quatro povoamentos de eucalipto, com 1; 2; 3 e 4 anos, e uma mata nativa de Cerrado como referência. Foram feitas avaliações do número de indivíduos de grupos taxonômicos da fauna do solo, e de características ecológicas dos grupos dessa fauna, como riqueza, riqueza média, índice de diversidade e de uniformidade. As coletas da fauna do solo foram realizadas nas estações úmida e seca. O maior número de indivíduos da fauna edáfica foi encontrado no povoamento de indivíduos com 1 ano de idade. A riqueza de espécies não diferiu entre as estações de coleta nas áreas avaliadas. Nos povoamentos com 1 e 2 anos de idade, aproximadamente 90% do total de indivíduos foram representados por Coleoptera e Formicidae, o que contribuiu para diminuir a uniformidade. Eucaliptos com menor tempo de implantação mostraram menor diversidade e uniformidade da fauna edáfica, entretanto houve recuperação destes atributos após dois anos de implantação.

Palavras-chave adicionais: diversidade de espécie; mata nativa; sazonalidade.

Introduction

The soil fauna plays an important role in biological processes of natural ecosystems and the study of its ecological characteristics allows it to be used as an indicator of soil quality and in the assessment of the severity of degraded agricultural ecosystems, as its diversity tends to decrease in managed soils (Wink et al., 2005).

The effects on the diversity of soil fauna have been the main focus of scientific investigations concerning forest replacement by monoculture systems, especially with regard to habitats quality loss and its ecological and evolutionary consequences (Sih et al., 2000). Some studies have demonstrated differences in diversity and species composition of soil fauna in different ecosystems, which results from the fragmentation process of balanced forests, such as Caatinga (Nunes et al., 2009), Atlantic rainforest (Menezes et al., 2009), the transitional area between Savanna and Caatinga (Lima et al., 2010), Savanna (Marchão et al. 2009) and Coca-crop forest (Nunes et al., 2012).

These changes occur due to plant litter presence with a variety of quite different organic and nutritional quality substrates in native systems, and due to habitat changes, through a single species crop. Thus, the number of ecological niches decreases, promoting intra and interspecific competition (Cole et al., 2006). With the alteration of the natural habitat, many species leave the area, die or are even extinct, until a new equilibrium is established (Hu et al. 1997).

Overall, the invertebrate community can be saved when the management system of secondary soil has an environmental structure that is similar to the original system. Thus, the soil fauna benefits from management systems that provide environmental conditions that favor the invertebrates reproduction and a higher quality and quantity of plant residues, which provide food and shelter (Baretta et al. 2003; Brown et al., 2004; Seeber et al., 2005).

There is much controversy about the environmental impact of eucalyptus ecosystems. The main criticism is due to the nutritional impoverishment of the soil, inhibiting the development of other plant species in eucalyptus understory, in addition to reduced biodiversity of soil organisms and also hydrological approach issues, such as the reduction of soil moisture and the lowering of the water table (Lima 1996).

Studies by Pellens & Garay (2000) comparing an edaphic macroarthropods community in an eucalyptus plantation with primary forest in the north of Espírito Santo state found lower density and fauna richness values in the eucalyptus due to a lower diversity and quality of plant residues in eucalyptus. In turn, Moço et al. (2005) observed, in the rainy season, fauna diversity in soil under eucalyptus was close to that found in the soils of preserved and not preserved forest. However, in the dry season, this diversity tended to decrease in soil under eucalyptus.

The objective of this research was to study, in the Savanna biome, the distribution of soil fauna in function of soil moisture in eucalyptus stands of different ages and in the remaining natural vegetation.

Material and methods

The study was conducted at the Fazenda Chapada Grande, located at Regeneracão City, Piauí State, Brazil. The soil, according to a soil exploratory recognition Survey of Piauí state (Jacomine, 1986), is an Yellow Oxissol. The region has an average annual temperature of 32 °C and with a mean annual precipitation of 1350 mm, with rainfall distributed from January to May (Equatorial Continental Scheme, with annual isohyets between 800-1400 mm). The climate, according to Köppen climate classification, is Aw '.

Four commercial eucalyptus stands have been chosen, in a sequence of 1, 2, 3 and 4 years, and also a preserved Cerrado vegetation as reference.

The eucalyptus stand with 1 year of age was implanted in 2010, using a spacing of 3.5 x 2.5 m. 1 Mg ha^{-1} of dolomitic lime per hectare was applied, and fertilized with 400 kg ha^{-1} of pre-planting reactive phosphate, based on 100 g $seedling^{-1}$ and NPK (6-30--6) at planting time. A year after planting, topdressing was carried out with 100g $seedling^{-1}$ of NPK (20-00- -20). There were held the following at the time of tillage: hand weeding in the area two months after planting and harrowing between lines three months after planting. The Eucalyptus stand with 2 years of age was introduced in 2009, with management and fertilization identical to 2010.

The eucalyptus stand with 3 years of age was implemented in 2008 in the spacing of 3.5 x 2.5 m. Liming was made in the dose of 1 Mg ha^{-1} limestone and was fertilized with 400 kg ha^{-1} of preplant reactive phosphate, based on 100 g $seedling^{-1}$ and in the addition of NPK (14-7-28) during planting, and then the addition of NPK (20-00-20) one year after planting. A year after planting, topdressing was conducted with 100 g $seedling^{-1}$ of NPK (20-00-20). The following procedures were performed: subsoiling at the time of tillage, hand weeding in the area two months after planting and harrowing between lines, three months after planting. 4 years old eucalyptus was implemented in 2010, with management and fertilization identical to those of 2009. In turn, the native Savanna vegetation is a primary preserved forest.

Eucalyptus seedlings were derived from the MA 2000 clone and grown in similar soil and climatic conditions, plan relief and and open clay textured soils (Table 1), classified as an Oxisol.

Table 1 - Granulometric composition of the soils under eucalyptus plantations and native Savanna.

Stand (age)	Coarse sand	Fine sand	Silt	Clay	Texture class
	--------------------	($g\ kg^{-1}$)	--------------------		
Eucalyptus (1 year)	111	190	297	402	Clay
Eucalyptus (2 years)	106	175	290	429	Clay
Eucalyptus (3 years)	114	186	297	404	Clay
Eucalyptus (4 years)	118	185	292	405	Clay
Savanna	146	178	257	419	Clay

Fauna collection was held in March 2011 (wet season) and September 2011 (dry season) in "pitfall" traps. These traps were formed by plastic recipients with 10 cm height and 10 cm diameter (containing 50% alcohol up to about 1/3 of its volume) and were buried in the soil up to its opening exactly being at soil level. A total of 8 traps were place, which were spaced 8 m between each one in the form of transect in the central part of each eucalyptus stand and Cerrado vegetation, where they remained for seven days.

The content of each flask from the trap was individually analyzed using Petri dish and caliper, under binocular microscope, and the number of individuals in each sample was recorded, with a field record being filled with the quantity of each species in each sample by sample site on the level of major taxonomic groups.

The soil fauna was assessed by the number of individuals per trap per day, fauna richness, which corresponds with the number of identified groups, and average richness, which represents the average number of individuals per trap. The average of these variables was compared by 5% Tukey test.

The total number of present taxonomic groups was evaluated by the Shannon diversity index, which was calculated using the following formula: $H = -\Sigma\ pi \times \log2\ pi$, where pi is the proportion of individuals belonging to the ith family.

For uniformity analysis, Pielou's Uniformity index was used, through the following expression: $U = H/\log nS$, where H corresponds to the Shannon index, n is the total number of individuals in the community and S is the total number of species found in each Coca-crop forest vegetation stand.

Results and discussion

The largest number of individuals was found in eucalyptus stand with 1 year of age in the two collections (Table 2). However, the highest standard error observed in this system shows a higher spatial heterogeneity, and demonstrates that in just a few traps certain groups of invertebrates were found. This is because of a probable mosaic structure, in which some microhabitats in these systems were able to attract more individuals, functioning as a kind of refuge for soil fauna (Dias et al., 2007).

Table 2 - Number individuals with their respective standard errors, total richness and average richness of soil fauna of species under eucalyptus plantations and native Savanna, in two seasons

Stand (age)	Individual $trap^{-1}\ day^{-1}$		Richness		Average richness	
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Eucalyptus (1 year)	97.69 a ± 14.78	41.31 a ± 8.83	16 a	13 a	9.10 a	8.80 a
Eucalyptus (2 years)	35.20 b ± 9.01	28.19ab ± 4.51	16 a	14 a	11.60 a	10.00 a
Eucalyptus (3 years)	20.42 c ± 4.66	10.19 c ± 2.18	15 a	13 a	11.50 a	8.30 a
Eucalyptus (4 years)	29.20 bc ± 8.19	23.62 b ± 3.37	15 a	14 a	11.53 a	10.30 a
Savanna	30.45 bc ± 6.63	11.30 c ± 2.63	15 a	18 a	11.83 a	10.80 a

***** Means followed by the same letter in the column do not differ by Tukey test ($P < 0.05$).

For Nunes et al. (2012) and Dauger et al. (2005), this type of spatial distribution usually occurs where different groups of soil fauna, mainly ants that are social insects, aggregate in function of micro-habitat factors, such as moisture and shading, or vegetation characteristics. A study performed by Frank & Furtado (2001) showed a significant increase of macrofauna in the soil next to the trees, both in the dry as in the rainy season, what was attributed to microclimate conditions generated under the treetop of these trees.

In the eucalyptus stand with 1 year of age, probably the organic matter input from treetops that was accumulated in the plant litter was not sufficient to generate organic residues into the soil that would able to maintain a representative and diverse fauna.

According to Vital (2007), in eucalypt stands with more than two years old, many leaves and fine branches fall, and within three to four years, the shell also starts to drop, producing up to 0.35 ton of plant litter by hectare, creating favorable conditions for food, shelter and reproduction of the soil fauna.

In turn, richness, which is the number of species within a given management system, has not differed between collection periods under any of vegetation covers, performing at very close values. It is important to note that, despite the number of individuals have been influenced by the estimated seasonal effect (P <0.05), this effect was not observed for groups richness among eucalyptus stands. This pattern suggests that the limitations that the edaphic community underwent during the dry season were not capable to reduce populations to levels that could impede their detection in samples, as also observed by Meneses et al. (2009) in forests successional stages.

In general, there was a decrease in the number of individuals and richness values in the dry season, except for the richness of native Savanna. Changes in soil moisture can modify the distribution and abundance of insects both to vertical and horizontal soil occupation. This is probably due to the microclimate generated in the soil, derived from higher rainfall, which, besides stimulating plant growth, and consequently plant litter production, increases the food supply for fauna, creates a favorable environment for soil biota growth and stimulates biological activity. Some studies have shown that in periods of low humidity the medium colonization conditions are limited to a few more resistant to drought species, to the detriment of others that may have migrated to the subsurface or to other areas (Nunes et al., 2009 and 2012).

In the rainy season, with a few exceptions, it was found that among 18 groups, 13 were present in all studied systems, what can be explained by the availability of water, while in the dry season only 10 groups of a total of 19 were present in all systems (Table 4). To Assad (1997), the rainfall seasonality affects the invertebrate populations, since water is their main activity limiting factor. For the author, the collembolan group, for example, are highly dependent on moisture and are found in humid or aquatic environments, and rarely in dry environments. The moisture shortage in the dry season may have restricted metabolic processes and increased the mortality rate of some taxonomic groups, such as the Acari and Collembola.

The largest number of individuals in eucalyptus stands of 1 and 2 years of age has not followed species diversity (Table 3), which showed far below values than the other systems studied in the wet season. These results show that the high number of fauna individuals in this time of year may have reduced diversity, because then there is a higher chance of a group being predominant, reducing diversity. In eucalyptus stands with 1 and 2 years of age, about 80% of individuals were represented by only two taxonomic groups: Coleoptera and Formicidae in the wet period (Table 4), what may show fauna poverty due to the absence of vegetation cover, which limits the number of ecological niches and favors the presence of pioneer organisms from early colonization, generating a smaller diversity.

Table 3 - Diversity Index and Uniformity Index of species under eucalyptus stands with 1, 2, 3 and 4 years of age and Cerrado native forest in the two seasons (wet and dry).

Stand (age)	Diversity Index		Uniformity Index	
	Wet season	Dry season	Wet season	Dry season
Eucalyptus (1 year)	0.73	1.93	0.18	0.52
Eucalyptus (2 years)	1.95	1.99	0.49	0.52
Eucalyptus (3 years)	2.97	2.22	0.76	0.60
Eucalyptus (4 years)	2.65	2.02	0.68	0.53
Savanna	2.22	2.63	0.57	0.63

However, there was an increase in the value of diversity in the eucalyptus stand with 1 year of age in the dry season, compared to the wet. This increase probably occurred because culture was in full treetop expansion stage and, due to strong winds at this time of year in the region, probably more deciduous material was added, mainly from leaves stratum, contributing to food supply and favoring an increase in the number of functional groups of soil fauna. Under these conditions, the fauna is shown at colonization stage, and not having a community with defined structure yet, variables such as richness, diversity and equability may still suffer major changes to its stabilization.

The Pielou's Index, which represents the uniformity of distribution of the number of individuals in the different groups of each area, showed variations in relation to eucalyptus age in both periods. The eucalyptus stand with 1 year of age showed a very low value of this index in the wet season (Table 3). This occurred because this system showed a large number of individuals, where there is a higher probability of one or two groups being predominating, which in this case are Coleoptera and Formicidae groups, as previously mentioned. However, in the dry season there was an increase in Pielou's index in this system, as there was a very dramatic decrease in the number of individuals, favoring a better distribution of fauna groups. In other systems, this index was not very discrepant between the two seasons due to the small fauna diversity variation with the change of season.

Table 4 - Relative Distribution (%) of taxonomic groups of soil fauna in eucalyptus stands and Cerrado native forest in the two seasons (dry and wet).

Taxonomic groups	Eucalyptus (1 year)	Eucalyptus (2 years)	Eucalyptus (3 years)	Eucalyptus (4 years)	Cerrado
			Wet season		
Acari	0.03	0.27	4.90	11.38	29.01
Aranae	1.33	1.22	10.49	1.96	2.58
Blatodea	1.48	1.35	3.15	1.00	1.02
Collembola	1.26	1.15	11.19	1.15	0.86
Coleoptera	61.35	63.19	26.57	32.80	34.32
Diplopoda	-	-	-	-	0.16
Diptera	5.91	6.29	12.47	6.32	2.03
Formicidae	17.22	15.76	20.28	33.40	23.92
Heteroptera	0.30	0.27	-	0.35	-
Homoptera	0.22	0.20	0.35	0.25	0.23
Hymenoptera	0.44	0.41	0.70	0.35	0.63
Isoptera	1.18	1.08	0.93	0.65	0.70
Coleoptera Larva	5.54	5.62	7.11	7.82	2.27
Diptera Larva	-	-	0.47	0.15	-
Lepdoptera	0.22	0.20	0.35	-	0.16
Orthoptera	2.81	2.57	0.35	2.36	1.41
Pseudoscorpionidae	0.30	0.27	0.70	0.05	0.70
Thysanoptera	0.15	0.14	-	-	-
	E1	E2	E3	E4	Forest
			Dry season		
Acari	0.12	0.34	-	-	1.69
Aranae	3.00	6.17	4.67	1.61	12.03
Blatodea	0.40	0.68	1.40	0.71	1.05
Collembola	0.12	-	0.23	-	3.16
Coleoptera	44.90	57.52	49.07	55.24	33.97
Diplopoda	-	-	-	0.10	0.42
Diptera	1.73	3.04	7.01	4.54	2.11
Formicidae	26.80	14.78	25.95	25.10	32.70
Heteroptera	0.35	0.08	0.23	0.60	0.21
Homoptera	-	-	-	0.10	2.74
Hymenoptera	0.52	1.44	3.04	4.33	0.84
Isoptera	-	0.25	1.40	0.81	4.22
Coleoptera Larva	0.69	1.27	0.93	3.33	2.11
Diptera Larva	-	-	-	0.50	0.42
Lepdoptera	0.06	0.08	-	1.01	0.21
Orthoptera	21.21	13.85	4.44	2.02	1.27
Pseudoscorpionidae	0.12	0.34	0.23	-	0.21
Scorpionidae	-	0.17	1.40	-	0.63

On the other hand, the forest in general had higher values in diversity and uniformity compared to the other studied systems in the dry season (Table 3). It is known that the more diverse is the vegetation cover, the higher will be plant litter heterogeneity, which will introduce higher diversity in fauna communities (Correia & Andrade, 2008).

The Savanna is a tropical forest in which a low vegetation, made primarily of grasses, coexists with trees and sparse shrubs (Hoffmann & Jackson, 2000), which could provide organic residues with several quite distinct nutritional and organic quality substrates (Warren & Zou, 2002). These conditions result in the appearance of more ecological niches and a complex feed network, contributing to reduced competition between species, and therefore favoring a large number of associated functional groups (Lavelle et al., 1997; Moço et al., 2005).

According to Barros et al. (2003), the vegetation cover has an important effect on the diversity of soil fauna, influencing even the taxonomic groups that are able to colonize the soil, as they are highly dependent organisms in the presence of specific habitats. Thus, humidity allied to the diversity of organic substrates also influences the presence of this or that taxonomic group. In this study, the Aranae group was present in higher proportion in the forest system in the dry period, in relation to eucalyptus stands (Table 4). For being a predator, arachnids stood out due to increased competition and fewer ecological niches, what favored its presence, as was also observed by Nunes et al. (2009 and 2012) in the Caatinga and Coca-crop forest, respectively.

In turn, the Pseudoscorpionida group was more abundant in eucalyptus in both seasons. It was also found that the Orthoptera group was more abundant in younger eucalyptus stands, independent on the period. Zanetti et al. (2003) found large amount of Orthoptera group individuals in two years of age eucalyptus, what includes this insect between herbivores associated with eucalyptus plantations, mainly because this insect multiplies rapidly. However, the authors observed that populations of Orthoptera were higher in areas of native cerrado vegetation that were adjacent to the eucalyptus plantations, what has not occurred in this study.

The eucalyptus plant litter has materials with high C/N ratio (> 25) and high levels of lignin and polyphenols, according to the studied plant part, and also high C/P and C/S relation, what helps to the slow decomposition of the residue (Pulrolnik et al., 2009). Possibly, the large amount of plant litter generated by eucalyptus, despite the low nutritional quality, provided certain environmental conditions that favored the reproduction and served as shelters for the species of soil fauna.

Conclusion

The soil fauna showed progressive increase in diversity and uniformity in relation to the age increase of the Eucalyptus stand.

The rainy season allowed the establishment of higher differences between different vegetation covers than the dry season.

References

Assad MLL (1997) Fauna do solo. In: Vargas, M.A.T.; Hungria, M. (ed.) Biologia dos solos dos Cerrados, EMBRAPA p.363-443.

Baretta D, Santos JCP, Mafra AL, Wildner LP, Miquelluti DJ (2003) Fauna edáfica avaliada por armadilhas de catação manual afetada pelo manejo do solo na região oeste catarinense. Revista de Ciências Agroveterinárias 2(1):97-106.

Barros E, Neves A, Blanchart E, Fernandes ECM, Wandelli E, Lavelle P (2003) Development of the soil macrofauna community under silvopastoral and agrosilvicultural systems in Amazonia. Pedobiologia 47(3) 273-280.

Brown GG, Moreno AG, Barois I, Fragoso C, Rojas P, Hernández B, Patrón JC (2004) Soil macrofauna in SE Mexican pastures and the effect of conversion from native to introduced pastures. Agriculture, Ecosystems and Environment 103(2):313-327.

Cole L, Bradford MA, Shawc PJA, Bardgettet RD (2006) The abundance, richness and functional role of soil meso and macrofauna in temperate grassland - A case study. Applied Soil Ecology 33(2):186-198.

Correia MEF, Andrade AG (2008) Formação de serapilheira e ciclagem de nutrientes. *In:* Santos GA, Camargo FAO (ed) Fundamentos da matéria orgânica do solo: ecossistemas tropicais e subtropicais, Metropole. p.137-158.

Dauger J, Purtauf T, Allspach A, Frisch J, Voigtländer K, Wolters V (2005) Local vs. Landscape controls on diversity: a test using surface-dwelling soil macroinvertebrates of differing mobility. Global Ecology and Biogeography 14(2):213-221.

Dias PF, Souto SM, Correia; MEF, Rodrigues, KM; Franco; AA (2007) Efeito de leguminosas arbóreas sobre a macrofauna do solo em pastagem de cv. Marandu. Pesquisa Agropecuária Tropical 37(1):38-44.

Frank IL, Furtado SC (2001) Sistemas silvipastoris: fundamentos e aplicabilidade. EMBRAPA Acre, 51 p. (Documentos 74).

Hu F, LI HX, Wu SM (1997) Differentiation of soil fauna populations in conventional tillage and no-tillage red soil ecosystems. Pedosphere 7(4):339-348.

Jacomine PKT (1986) Levantamento exploratorio - reconhecimento de solos do estado do Piaui. EMBRAPA-SNLCS/ SUDENE-DRN. 782p.

Lavelle P, Bignell D, Lepage M, Wolters V, Roger P, Ineson P, Heal OW, Dhillion S (1997) Soil function in a changing world: the role of invertebrate ecosystem engineers. European Journal Soil Biology 33(1):159-193.

Lima WP (1996) Impacto ambiental do eucalipto. EDUSP. 301p.

Lima SS, Aquino AM, Leite LFC, Velásques E, Lavelle P (2010) Relação entre macrofauna edáfica e atributos químicos do solo em diferentes agroecossistemas. Pesquisa Agropecuária Brasileira 45(3):322-331.

Marchão, RL, Lavelle P, Celini L, Balbino LC, Vilela L, Becquer T (2009) Soil macrofauna under integrated crop- livestock systems in a Brazilian Cerrado Ferralsol. Pesquisa Agropecuária Brasileira 44(8):1011-1020.

Menezes CEG, Brown GG, Constantino R, Louzada JNC, Luizão FJ, Morais JW, Zanetti R (2009) Macrofauna edáfica em estágios sucessionais de floresta estacional semidecidual e pastagem mista em Pinheiras (RJ), Revista Brasileira Ciência do Solo 33(6):1647-1656.

Moço MK, Gama-Rodrigues EF, Gama-Rodrigues

AC, Correia MEF (2005) Caracterização da fauna edáfica em diferentes coberturas vegetais na região norte fluminense. Revista Brasileira de Ciência do Solo 29(4):555-564.

Nunes, LAPL, Araújo Filho JA, Menezes RIQ (2009) Diversidade da fauna edáfica em solos submetidos a diferentes sistemas de manejo no semi-árido nordestino. Scientia Agrária 25(1): 43-49.

Nunes LAPL, Silva DIB, Araújo ASF, Leite LFC, Correia MEF (2012) Caracterização da fauna edáfica em sistemas de manejo para produção de forragens no Estado do Piauí. Revista Ciência Agronômica 43(1):30-37.

Pellens R, Garay I (2000) Edaphic macroarthopod communities in fast-growing plantations of Eucalyptus grandisHill ex Maid (Myrtaceae) and Acacia mangium Wild (Leguminosae) in Brazil. European Journal Soil Biology 35(1):77-89.

Pulrolnik K, Barros NF, Silva IR, Novais R F, Brandani CB (2009) Estoques de carbono e nitrogênio em frações lábeis e estáveis da matéria orgânica de solos sob eucalipto, pastagem e cerrado no Vale do Jequitinhonha – MG. Revista Brasileira de Ciência do Solo 33(5):1125-1136.

Seeber J, Seeber GUH, Kossler W (2005) Abundance and trophic structure of macredecomposers on alpine pastureland (Central Alps, Tyrol): effects of abandonment of pasturing. Pedobiologia 49(2):221-228.

Sih A, Jonsson BG, Luikart G (2000) Habitat loss: Ecological, evolutionary and genetic consequences. Trends in Ecology and Evolution 15(4):132-134.

Vital MHF (2007) Impacto ambiental de florestas de Eucalipto. Revista do BNDES 14(28):235-276.

Zanetti R, Silva AS, Moura MA, Zanuncio JC (2003) Ocorrência do Gafanhoto-do-Coqueiro *Eutropidacris cristata* (Orthoptera: acrididae) atacando plantas de eucalipto em Minas Gerais. Revista Árvore 27(1):105-107.

Warren MW, Zou X (2002) Soil macrofauna and litter nutrients in three tropical tree plantations on a disturbed site in Puerto Rico. Forest Ecology Management 170(1):161-171.

Wink C, Guedes JVC, Fagundes CK, Rovedder AP (2005) Insetos edáficos como indicadores da qualidade ambiental. Revista de Ciências Agroveterinárias 4(1):60-71.