CAPÍTULO 6

Soil Fauna Influenced by Organic and Mineral Fertilization in Triticum aestivum Cultivation

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INTRODUCTION

Wheat (Triticum aestivum) is one of the most important cereals cultivated in Brazil, occupying approximately 2.71 million hectares (CONAB, 2021). It plays an important role in crop rotation systems under no-tillage management with maize and soybean, contributing to the sustainability of agricultural production systems (Smanhotto et al., 2006). Due to its high capacity for dry matter production, wheat provides substantial soil cover during a large part of the year (Kliemann et al., 2006), creating favorable conditions for the development of soil invertebrate populations (Santos et al., 2008).

Brazil also stands out as a major producer of poultry under confined systems (Silva et al., 2011), which enables the use of poultry litter as a fertilizer source in agricultural systems (Menezes et al., 2003). Therefore, organic fertilization has become an attractive alternative due to nutrient recycling, reduction of mineral fertilizer costs, and mitigation of environmental impacts (Santos et al., 2011). In addition, the incorporation of organic residues may influence soil biota, since these materials serve as a food source for soil organisms (Baretta et al., 2003), promoting biological changes in the soil environment (Alves et al., 2006). These effects may be beneficial when residues are applied in appropriate amounts, but potentially harmful when excessive doses are used (Baretta et al., 2003; Lindberg, 2003).

Soil fauna can be considered an important indicator of soil quality because these organisms directly influence the physical, chemical, and biological characteristics of soils (Silva et al., 2006; Steffen et al., 2007). Their high sensitivity to environmental changes allows them to reflect the impacts of management practices adopted in agricultural systems (Rovedder et al., 2004). Both the absence of vegetation cover (Baretta et al., 2006) and variations in plant cover (Santos et al., 2008) can significantly affect soil fauna communities. Therefore, winter cover crops used for soil protection may also influence the biological community in the soil (Silva et al., 2013).

Although the economic importance of wheat and the nutritional potential of poultry litter are well documented, their effects on soil fauna communities are still insufficiently investigated. Thus, this study aimed to determine whether organic fertilization with poultry litter can replace mineral fertilization with respect to its effects on soil mesofauna and macrofauna under wheat cultivation.

MATERIALS AND METHODS

The experiment was conducted in an experimental area of the Federal University of Santa Maria (UFSM), Frederico Westphalen campus, Rio Grande do Sul, Brazil (27°23′45.75″ S and 53°25′45.92″ W), at an altitude of 566 m. The soil in the experimental area is classified as a Red Oxisol according to the Brazilian Soil Classification System (Embrapa, 2006). The regional climate is classified as Cfa according to Köppen. The terrain is gently undulating, and the area had been cultivated under a no-tillage system for six years.

Soil analysis was performed following the methodology proposed by Embrapa (1997), and the soil presented the following physical and chemical characteristics: 62% clay; pH (H_2O) of 5.8; 5.3 mg dm^{-3} of P (Mehlich-1); 288 mg dm^{-3} of K; 7.6 cmolc dm^{-3} of Ca; 48 cmolc dm^{-3} of Mg; and 3.5% organic matter. Fertilization recommendations were based on the Fertilization and

Liming Manual for the states of Rio Grande do Sul and Santa Catarina (Comissão…, 2004). Poultry litter was used as the organic fertilizer source. The recommended rate was applied in two stages: 50% at sowing and 50% as topdressing at 30 days after sowing (DAS). The chemical composition of the poultry litter was determined according to the methodology described by Tedesco et al. (1995).

	Chemical composition (%)						
	pH	N	OM	Ca	Mg	P_2O_5	K_2O
Poultry bedding	7,1	4,8	68,47	6,37	1,13	4,03	4,76

Table 1. Chemical composition of poultry litter.

The experimental design consisted of a randomized block design with five treatments, comprising three poultry litter doses (zero – without fertilization = control –, one (1×) and four (4×) times the recommended poultry litter rate), mineral fertilization (MF), and a treatment combining mineral and organic fertilization (MF + Org), with four replications. The treatments corresponding to one and four times the recommended rate were equivalent to 620 and 2480 kg ha^{-1} of poultry litter, respectively (Comissão…, 2004). Each plot covered an area of 25 m^2, totaling 500 m^2 of experimental area, in addition to a cultivated border consisting of a 3-m strip surrounding the blocks.

The experiment was conducted and evaluated over two growing seasons (2013–2014 and 2014–2015) under wheat cultivation (Triticum aestivum), which was established 10 days after weed desiccation using the herbicide glyphosate at a rate of 3 L ha^{-1} of the commercial product. Sowing was performed with 17 cm spacing between rows and 70 seeds per linear meter, corresponding to approximately 4,100,000 seeds ha^{-1}. Weed control after sowing, in both growing seasons, was carried out using the herbicide ALLY® at a rate of 4 g a.i. ha^{-1}.

Soil fauna sampling was performed using PROVID traps (Antoniolli et al., 2006), which capture organisms belonging to the mesofauna and macrofauna groups, characterized by higher mobility in the soil. The traps remained in the field for seven days and contained 250 mL of 70% alcohol for the preservation of the collected organisms.

The individuals were identified at the order level using binocular stereomicroscopes with 40× magnification (Buzzi, 2008). Subsequently, the number of individuals (NI) within each order was counted, and the number of orders was determined according to the functional role of the organisms in the soil, following Lavelle (1996).

Based on the obtained data, the following indices were calculated: organism abundance; Margalef richness index; Simpson dominance index; Shannon diversity index; and Pielou evenness index (Odum, 1988).

The results were subjected to F-test analysis, and when significant effects were detected, the Scott–Knott test was used for mean comparison of the variables related to orders and diversity indices, while the Tukey test was applied for functional groups ($P < 0.05$) (Ferreira, 2008).

RESULTS AND DISCUSSION

The results of the soil fauna evaluation in wheat cultivation revealed the presence of organisms belonging to the following orders: Acarina, Araneae, Coleoptera, Collembola, Hymenoptera, and Orthoptera. Among these groups, the orders Collembola and Hymenoptera were the most abundant. A total of 5,500 individuals were collected during the two years of evaluation, with a predominance of the order Hymenoptera—represented by ants—, totaling 2,566 individuals, which corresponds to approximately 47% of the total organisms recorded (Table 2).

The marked presence of ants in terrestrial ecosystems, compared to other groups of organisms, is commonly reported in the literature (ELLWOOD & FOSTER, 2004; SOUZA et al., 2008; ZARDO et al., 2010; MAESTRI et al., 2013).

This group of organisms plays an important role as an ecological indicator of environmental changes, particularly in the recovery of degraded areas (BARETTA et al., 2003). Furthermore, ants contribute to nutrient cycling, predation, seed dispersal, plant pollination, and the physical structuring of the soil (PEREIRA et al., 2007).

The order Collembola was the second most expressive group in this experiment. Of the 5,500 individuals collected, 1,730 belonged to this group, corresponding to 31.4% of the total organisms (Table 2). Collembolans are considered important indicators of soil quality (DAMÉ et al., 1996). Their main diet consists of plant residues and fungi, although they may also serve as a food source for predatory organisms. Together with mites, they constitute the largest population within the soil mesofauna (COLEMAN & CROSSLEY, 1995; LAVELLE, 1996). In addition, these organisms are considered important indicators of soil quality because they are highly sensitive to environmental changes (BARETTA et al., 2008).

Treatments	Aca	Aran	Coleo	Coll	Hym	Ort
Control	40	4	32	246	410	34
MF	66	12	98	246	546	168
MF + Org	88	14	16	526	322	140
1 x recommended	52	10	30	306	432	68
4 x recommended	126	12	86	406	856	108
Total	372	52	262	1730	2566	518

Abbreviations: Aca = ácaro; Ara = aranha; Coleo = coleóptero; Coll = Collembola; Dip = diptera; Hym = hymenoptera; Ort = Orthóptera.

Table 2. Total number of individuals captured during two wheat growing seasons.

A significant increase in the number of individuals belonging to the orders Acarina, Coleoptera, Collembola, Hymenoptera, and Orthoptera was observed at the dose of 2480 kg ha^{-1} compared to 620 kg ha^{-1} of poultry litter (Table 3). The addition of organic residues influences soil biota, particularly due to the direct effect of the residue itself (poultry litter), which serves as a food source for soil organisms (BARETTA et al., 2007).

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Treatment	Aca	Ara	Coleo	Coll	Hym	Ort
Control	5 C	1 A	4 B	31 C	51 C	4 D
MF	8 C	2 A	12 A	31 C	68 B	21 A
MF + org	11 B	2 A	2 B	65 A	40 D	18 A
1 x recommended	7 C	1 A	4 B	38 C	54 C	9 C
4 x recommended	16 A	2 A	11 A	51 B	107 A	14 B
CV (%)	18,10	50,64	29,03	11,54	8,95	18,25

Aca =

Acarina; Ara = Araneae; Coleo = Coleoptera; Coll = Collembola; Dip = Diptera; Hym = Hymenoptera; Ort = Orthoptera.

Means followed by the same uppercase letter in the column do not differ from each other according to the Scott–Knott test ($P < 0.05$).

Table 3. Mean number of individuals captured during two wheat growing seasons.

The best results for the orders Coleoptera and Orthoptera were obtained with mineral fertilization, with no statistical difference compared to the mineral + organic fertilization treatment (Table 2). The highest population of individuals belonging to the order Collembola occurred in the mineral + organic fertilization treatment. Large populations in plots that received mineral fertilization may be the result of the rapid availability of nutrients provided by this type of fertilization. Consequently, plant growth may increase, resulting in a greater return of organic matter to the soil and increased food availability for soil fauna (ALVES, 2007).

No differences among treatments were observed for the Margalef richness index (Table 4). The highest value of Simpson dominance occurred in the control treatment (Table 4) and differed from the other treatments. This result is explained by the presence of organisms belonging to the orders Hymenoptera and Collembola, which represented 54% and 32%, respectively, of the individuals collected in this treatment (Table 2).

The organisms belonging to the order Hymenoptera were mainly represented by ants, and the most probable reason for the high occurrence of individuals of this order may be their high mobility capacity (ALVES, 2007; ALVES et al., 2006). The high number of individuals of the order Collembola in this environment also indicates a favorable condition for soil health, since, due to their position in the trophic chain, their functional role in processes related to organic matter dynamics, and their sensitivity to environmental disturbances, Collembola can be considered an important component of soil quality (COLEMAN & HENDRIX, 2000).

The most likely explanation for the high occurrence of these organism groups in the control treatment is the characteristics of the vegetation cover present in this environment, which is an important factor determining the selectivity of the organisms composing the soil community (MOÇO et al., 2005).

Treatments	Indices				
	Abundance	*Margalef*	*Simpson*	*Shannon*	*Pielou*
Control	95,75 D	0,987 A	0,39 A	0,496 C	0,673 B
Mineral	142,00 B	1,010 A	0,311 C	0,602 A	0,774 A
Mineral + organic	138,25 B	1,014 A	0,335 C	0,559 B	0,719 B
1 x recommended	112,25 C	1,060 A	0,359 B	0,538 B	0,691 B
4 x recommended	199,25 A	0,945 A	0,369 B	0,545 B	0,699 B
CV (%)	7,60	13,54	3,72	5,43	3,56

*Means followed by the same uppercase letter in the column do not differ from each other according to the Tukey test.

Table 4. Abundance index, Margalef richness, Simpson dominance, Shannon diversity, and Pielou evenness under different fertilization treatments in wheat cultivation.

The effects of the treatments on the Shannon and Pielou indices were similar. For both indices, the mineral fertilization treatment showed the best results, with significant differences compared to the other treatments (Table 4). This may be explained by the population fluctuation of the orders Coleoptera, Orthoptera, and Hymenoptera, which allowed a better distribution of individuals among populations in this treatment.

No significant differences were observed among the poultry litter doses for the Simpson dominance index (Table 4). The same was observed for the mineral and mineral + organic fertilization treatments, whose mean values were the lowest and differed from the other treatments. The highest dominance occurred in the control treatment, with significant differences compared to all other treatments. The large number of individuals belonging to the orders Hymenoptera and Collembola was responsible for the greater dominance observed in the control. This result highlights the importance of organic residues as a possible factor influencing variations in soil fauna groups, since the absence of fertilization in this treatment may have resulted in lower plant growth and, consequently, lower availability of organic material that could serve as food for soil organisms.

The populations of functional groups differed significantly among treatments (Figure 1). The treatment with the highest poultry litter application rate (4 × recommended) produced the best results for the social and other functional groups. Once again, it is important to emphasize the role of organic residue addition as a food base for soil fauna, both through the direct effect of the residue itself and the indirect effect of increased nutrient availability for plant growth and straw production, resulting from the application of organic fertilization (BARETTA et al., 2007).

Among all functional groups identified in this study, social insects were the most abundant (1,283 individuals) (Figure 1). This group consisted mainly of ants. The high abundance of individuals belonging to the order Hymenoptera is commonly reported in the literature (MAESTRI et al., 2013; SOUZA et al., 2008; ZARDO et al., 2010), since this order may inhibit the presence of other orders or interfere with the availability of plant residues for other groups of organisms (QUADROS et al., 2009).

The importance of social insects is particularly evident in decomposition systems, either directly or indirectly, due to their feeding habits, which may be saprophagous and/or predatory (MOÇO et al., 2005). In addition, they contribute to nutrient cycling, plant dispersal, and pollination (PEREIRA et al., 2007). They also play an important role in the soil aggregation process (PINHEIRO, 1996; OLIVEIRA et al., 2012).

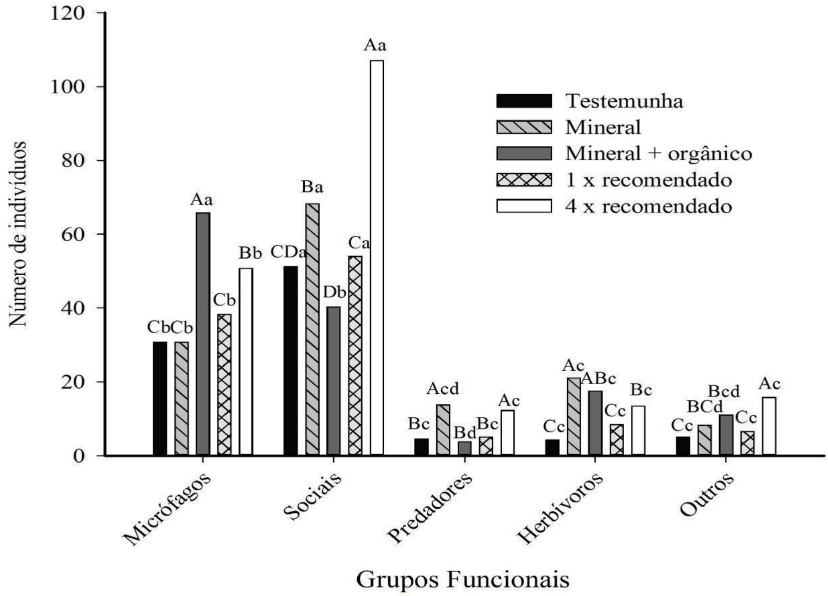

Figure 1. Functional groups of soil fauna under different fertilization treatments (Control, Mineral, Mineral + organic, 1× recommended, and 4× recommended) in wheat cultivation.

The second most expressive functional group was the microphages (Figure 1), represented by Collembola. The functional activity of these organisms is based on the predation of other microorganisms (TORDOFF et al., 2008), as well as the fragmentation of organic matter and enzyme production, which indirectly influences soil fertility (BERG et al., 2004; YANG et al., 2012).

The microphage group, represented by Collembola, showed the best results under the combined mineral and organic fertilization treatment. For the other functional groups, no differences were observed among the mineral, integrated, and organic fertilization systems.

CONCLUSIONS

Fertilization management significantly influenced soil fauna structure in wheat cultivation. The highest poultry litter dose increased the abundance of several taxonomic groups, particularly Acarina, Coleoptera, Collembola, Hymenoptera, and Orthoptera, highlighting the importance of organic residue inputs for soil biological activity.

Mineral fertilization promoted higher Shannon diversity and Pielou evenness, indicating a more balanced distribution of soil fauna populations, whereas the control treatment showed higher Simpson dominance, mainly due to the predominance of Hymenoptera and Collembola.

Overall, the results demonstrate that fertilization strategies modify soil fauna communities, with organic residues acting as an important energy source that supports soil biodiversity in wheat cropping systems.

REFERENCES

Alves, M. V. (2007). Fauna do solo influenciada pelo uso de fertilizantes minerais e dejetos suínos na sucessão aveia–milho sob semeadura direta (Master's dissertation). Universidade do Estado de Santa Catarina (UDESC), Centro de Ciências Agroveterinárias, Lages, Brazil.

Alves, M. V., Baretta, D., & Cardoso, E. J. B. N. (2006). Soil fauna in different cultivation systems in the state of São Paulo. Revista de Ciências Agroveterinárias, 5(1), 33–43.

Baretta, D. (2003). Biological soil attributes in different agroecosystems in southern Brazil (Master's dissertation). Universidade do Estado de Santa Catarina, Lages, Brazil.

Baretta, D., et al. (2003). Soil fauna evaluated by manual collection traps affected by soil management in western Santa Catarina. Revista de Ciências Agroveterinárias, 2, 97–106.

Baretta, D., et al. (2006). Multivariate analysis of soil fauna in different soil tillage and cropping systems. Pesquisa Agropecuária Brasileira, 41(11), 1675–1679.

Baretta, D., et al. (2007). Earthworm populations sampled using collection methods in Atlantic forests with Araucaria angustifolia. Scientia Agricola, 64, 384–392.

Baretta, D., et al. (2008). Collembolans (Hexapoda: Collembola) as bioindicators of soil quality in areas with Araucaria angustifolia. Revista Brasileira de Ciência do Solo, 32(special issue), 2693–2699.

Berg, M. P., Stoffer, M., & van den Heuvel, H. H. (2004). Feeding guilds in Collembola based on digestive enzymes. Pedobiologia, 48, 589–601.

Buzzi, Z. J. (2008). Entomologia didática (4th ed.). Curitiba: Editora UFPR.

Calegari, A. (2001). Crop rotation and cover crops as support for no-tillage systems. In Congresso Brasileiro de Ciência do Solo. Londrina: Sociedade Brasileira de Ciência do Solo.

Coleman, D. C., & Hendrix, P. F. (2000). Invertebrates as webmasters in ecosystems. London: CABI Publishing.

Crusciol, C. A. C., Moro, E., Lima, E. V., & Andreotti, M. (2008). Decomposition and macronutrient release rates of black oat straw under no-tillage. Bragantia, 67(2), 481–489.

Companhia Nacional de Abastecimento (CONAB). (2021). Acompanhamento da safra brasileira de grãos 2020/2021. Brasília, Brazil.

Damé, P. R. V., et al. (1996). Effects of burning followed by grazing or deferment on residue, soil temperature and mesofauna of a natural pasture. Ciência Rural, 26(3), 391–396.

Ellwood, M. D. F., & Foster, W. A. (2004). Doubling the estimate of invertebrate biomass in a rainforest canopy. Nature, 429, 549–551.

Fraser, P. M. (1994). The impact of soil and crop management practices on soil macrofauna. In C. E. Pankhurst, B. M. Doube, & V. V. S. R. Gupta (Eds.), Soil biota: Management in sustainable farming systems (pp. 125–132). CSIRO.

Kliemann, H. J., Braz, A. J. P. B., & Silveira, P. M. (2006). Decomposition rates of cover crop residues in a dystroferric Red Oxisol. Pesquisa Agropecuária Tropical, 36, 21–28.

Lavelle, P. (1996). Diversity of soil fauna and ecosystem function. Biology International, 33, 3–16.

Lindberg, N. (2003). Soil fauna and global change: Responses to experimental drought, irrigation, fertilisation and soil warming (Doctoral thesis). Swedish University of Agricultural Sciences.

Maestri, R., Leite, M. A. S., Schmitt, L. Z., & Restello, R. M. (2013). Effect of native forest and eucalyptus plantation on arthropod richness in litter. Perspectiva, 37, 31–40.

Menezes, J. F. S., Alvarenga, R. C., Andrade, C. L. T., Konzen, E. A., & Pimenta, F. F. (2003). Use of organic residues for grain production under no-tillage and environmental impact assessment. Revista Plantio Direto, 1, 30–35.

Moço, M. K. S., Gama-Rodrigues, E. F., Gama-Rodrigues, A. C., & Correia, M. E. F. (2005). Soil fauna characterization under different vegetation covers in northern Rio de Janeiro state. Revista Brasileira de Ciência do Solo, 29, 555–564.

Oliveira, M. I. L., Benito, N. P., Camargo, A. J. A., Guimarães, M. F., & Brossard, M. (2012). Activity of Cornitermes cumulans colonies on soil macro- and microaggregated structures in greenhouse conditions. Semina: Ciências Agrárias, 33, 1733–1744.

Pereira, M. P. S., Queiroz, J. M., Souza, G. O., & Mayhé-Nunes, A. J. (2007). Influence of litter heterogeneity on ants nesting in dead branches in native forest and eucalyptus plantation. Neotropical Biology and Conservation, 2(3), 161–164.

Pinheiro, L. B. A. (1996). Study of soil macrofauna in sugarcane cultivation under different harvesting systems (green and burned) (Master's dissertation). Universidade Federal Rural do Rio de Janeiro.

Quadros, J. V., Antoniolli, Z. I., Casali, C. A., Denega, G. L., Lupatini, M., Steffen, R. B., & Pujol, S. B. (2009). Soil fauna in potato, soybean, bean, and maize cropping systems. Ciência e Natura, 31(1), 115–130.

Rovedder, A. P., Antoniolli, Z. I., Spagnollo, E., & Venturini, S. F. (2004). Soil fauna in soils susceptible to arenization in southwestern Rio Grande do Sul. Revista de Ciências Agroveterinárias, 3, 87–96.

Santos, D. H., Silva, M. A., Tiritan, C. S., Foloni, J. S. S., & Echer, F. R. (2011). Technological quality of sugarcane under fertilization with filter cake enriched with soluble phosphate. Revista Brasileira de Engenharia Agrícola e Ambiental, 15, 443–449.

Santos, G. G., Silveira, P. M., Marchão, R. L., Becquer, T., & Balbino, L. C. (2008). Soil macrofauna associated with cover crops under no-tillage in a Red Oxisol of the Cerrado. Pesquisa Agropecuária Brasileira, 43(1), 115–122.

Silva, C. F., Pereira, G. H. A., Pereira, M. G., Silva, A. N., & Menezes, L. F. T. (2013). Soil fauna in periodically flooded areas of the Marambaia Restinga. Revista Brasileira de Ciência do Solo, 37, 587–595.

Silva, R. F., Aquino, A. M., Mercante, F. M., & Guimarães, M. F. (2006). Soil macrofauna under different production systems in a Cerrado Oxisol. Pesquisa Agropecuária Brasileira, 41(4), 697–704.

Silva, J., Jucksch, I., Maia, C. I., Feres, A., & Tavares, R. C. (2012). Soil fauna in coffee management systems. Journal of Biotechnology and Biodiversity, 3(2), 59–71.

Silva, R. F., Corassa, G. M., Bertollo, G. M., Santi, A. L., & Steffen, R. B. (2013). Soil fauna influenced by cover crops and intercropping systems. Pesquisa Agropecuária Tropical, 43(2).

Silva, T. R., Menezes, J. F. S., Simon, G. A., Assis, R. L., Santos, C. J. L., & Gomes, G. V. (2011). Maize cultivation and phosphorus availability under poultry litter fertilization. Revista Brasileira de Engenharia Agrícola e Ambiental, 15.

Smanhotto, A., et al. (2006). Physical and physiological characteristics influencing industrial quality of wheat and triticale cultivars. Revista Brasileira de Engenharia Agrícola e Ambiental, 10(4), 867–872.

Souza, R. C., Correia, M. E. F., Pereira, M. G., Silva, E. M. R., Paula, R. R., & Menezes, L. F. T. (2008). Soil fauna community structure in forest fragments of Marambaia Restinga, RJ. Revista Brasileira de Ciências Agrárias, 3(1), 49–57.

Steffen, R. B., Antoniolli, Z. I., & Steffen, G. P. K. (2007). Evaluation of substrates for reproduction of native collembolans under laboratory conditions. Ciência Florestal, 17(3), 265–269.

Tarrá, I. L. C., Luizão, F. J., Wandelli, E. V., Teixeira, W. G., Morais, W. J., Fernandes, E. C. M., Brochel, K. V., & Pérez, N. V. (2012). Functional groups of soil macrofauna and macropores in agroforestry systems in Central Amazonia. Prospectiva, 10(1), 6–17.

Tordoff, G. M., Boddy, L., & Jones, T. H. (2008). Species-specific impacts of Collembola grazing on fungal foraging ecology. Soil Biology & Biochemistry, 40, 434–442.

Yang, X., Yang, Z., Warren, M. W., & Chen, J. (2012). Mechanical fragmentation enhances the contribution of Collembola to leaf litter decomposition. European Journal of Soil Biology, 53, 23–31.

Zardo, D. C., Carneiro, A. P., Lima, L. G., & Santos-Filho, M. (2010). Arthropod community associated with litter in Cerrado and gallery forest ecosystems. Revista Uniara, 13(2).