e-ISSN 1983-4063 - *www.agro.ufg.br/pat* - Pesq. Agropec. Trop., Goiânia, v. 52, e70416, 2022

Research Article

Feeding activity of soil fauna in production systems under cover crop straws[1]

Arlini Rodrigues Fialho[2], Darliane de Castro Santos[2],
Cintia Carla Niva[3], Jaqueline Balbina Gomes Ferreira[2], Tiago do Prado Paim[2]

ABSTRACT

To preserve a desirable level of soil quality, especially taking into consideration its health and sustainability, is not an easy task, due to the numerous factors that influence it. This study aimed to measure the feeding activity of soil fauna in production systems under cover crop straws sampled at the depth of 0-8.0 cm. A randomized blocks design, with four replicates and eight treatments, was used, corresponding to soybean cultivation under the following cover crop straws: maize monoculture; maize intercropped with *Urochloa ruziziensis*; *U. ruziziensis* monoculture; sorghum intercropped with *U. ruziziensis*; sorghum monoculture; sunflower intercropped with *U. ruziziensis*; mix (millet + *Crotalaria spectabilis* + *U. ruziziensis*); and a fallow treatment. At the depth of 1.0 cm, there was a variation of 63.59-37.06 % for consumption among the treatments, with the highest consumption for the mix, if compared to the fallow treatment. At the depth of 2.0-7.0 cm, the consumption did not vary among the treatments. For the depth of 8.0 cm, the fallow treatment presented the highest consumption (45.76 %; $p < 0.05$), when compared to sunflower intercropped with *U. ruziziensis* (20.51 %), sorghum (20.58 %) and sorghum intercropped with *U. ruziziensis* (18.96 %).

KEYWORDS: *Glycine max*, *Urochloa ruziziensis*, soil quality.

RESUMO

Atividade alimentar da fauna do solo em sistemas de produção sob palhadas de plantas de cobertura

Conservar o nível desejável de qualidade do solo, especialmente prezando sua saúde e sustentabilidade, não é tarefa simples, devido aos inúmeros fatores que o influenciam. Objetivou-se mensurar a atividade alimentar da fauna do solo em sistemas de produção sob palhadas de plantas de cobertura amostradas à profundidade de 0-8,0 cm. Foi adotado delineamento em blocos casualizados, com quatro repetições e oito tratamentos, que corresponderam ao cultivo de soja sob palhadas de plantas de cobertura: monocultivo de milho; milho consorciado com *Urochloa ruziziensis*; monocultivo de *U. ruziziensis*; sorgo consorciado com *U. ruziziensis*; monocultivo de sorgo; girassol consorciado com *U. ruziziensis*; mix (milheto + *Crotalaria spectabilis* + *U. ruziziensis*) e pousio. À profundidade de 1,0 cm, houve variação de 63,59-37,06 % no consumo entre os tratamentos, com maior consumo para o mix, em comparação ao pousio. À profundidade de 2,0-7,0 cm, o consumo não variou entre os tratamentos. Para a profundidade de 8,0 cm, o pousio apresentou o maior consumo (45,76 %; $p < 0,05$), em comparação ao girassol consorciado com *U. ruziziensis* (20,51 %), sorgo (20,58 %) e sorgo consorciado com *U. ruziziensis* (18,96 %).

PALAVRAS-CHAVE: *Glycine max*, *Urochloa ruziziensis*, qualidade do solo.

INTRODUCTION

Soil biological attributes are important indicators of changes caused by agricultural practices, being useful for monitoring, planning and evaluating management practices (Ferreira et al. 2018).

The permanent maintenance of living plants and/or crops is only possible due to the fact that the soil surface plays an essential role in sustaining the soil biodiversity by acting as a source of balance in the nutrient cycling rate, protecting the soil from direct sunlight, adjusting the soil temperature and moisture, and offering refuge and habitat for the soil fauna (Menandro et al. 2019).

The soil fauna consists of numerous species of invertebrates (including microfauna, mesofauna and macrofauna) that contribute to organic matter decomposition and soil formation, besides interacting with microorganisms, thus contributing to the maintenance of the soil health and fertility (Brown

[1] Received: Oct. 01, 2021. Accepted: Mar. 14, 2022. Published: May 31, 2022. DOI: 10.1590/1983-40632022v5270416.
[2] Instituto Federal de Educação, Ciência e Tecnologia Goiano, Campus Rio Verde, Rio Verde, GO, Brasil.
E-mail/ORCID: arlinirodrigues@hotmail.com/0000-0002-8658-6131; darliane.castro@ifgoiano.edu.br/0000-0001-6859-056X; balbinajaqueline@gmail.com/0000-0001-9377-1602; tiago.paim@ifgoiano.edu.br/0000-0002-9486-7128.
[3] Empresa Brasileira de Pesquisa Agropecuária (Embrapa Cerrados), Planaltina, DF, Brasil.
E-mail/ORCID: cintia.niva@embrapa.br/0000-0002-1481-2240.

et al. 2015). The absence or reduction of these organisms in the soil surface layer (0-10 cm) may cause problems in the soil structuring and functioning (Baretta et al. 2011). By studying the soil fauna, besides evaluating the soil quality, it is possible to better understand the production systems occurring in the soil (Parron et al. 2015).

To preserve a desirable level of soil quality, especially taking into consideration its health and sustainability, is not an easy task, due to the numerous factors that influence the soil quality, which include climate conditions, absence of soil organic matter and different plants and managements (Cherubin et al. 2015), especially soybean, maize, millet, sorghum, crotalaria, sunflower and tropical forage grasses, intercropped or in monoculture (Loss et al. 2011).

Although the soil quality evaluation is mainly based on laboratory methods, the soil quality evaluation in the field allows farmers, technicians and researchers to evaluate soils quickly and economically. The bait-lamina method is an alternative created by Von Törne (1990), and consists of measuring the feeding activity of soil invertebrates through blades inserted vertically into the soil. Studies using this method are still scarce in Brazil (Römbke et al. 2006, Musso et al. 2014, Santana et al. 2018, Pessotto et al. 2020).

Thus, this study aimed to measure the feeding activity of the soil fauna in production systems under cover crop straws sampled at the soil depth of 0-8.0 cm.

MATERIAL AND METHODS

The experiment was carried out in Rio Verde, Goiás State, Brazil (17º47'53"S, 50º55'41"W and altitude of 715 m).

The soil of the experimental area is classified as Latossolo Vermelho Distrófico (Santos et al. 2018) or Oxisol (USDA 2014), with the following physical characteristics: 52.0 % of sand, 40.5 % of clay and 7.5 % of silt (Embrapa 2017). The following indices were observed during the study period: a minimum temperature of 19 ºC, maximum temperature of 29 ºC and rainfall of 247 mm were recorded in December 2018; and a minimum temperature of 15 ºC, maximum temperature of 30 ºC and rainfall of 197 mm were recorded in December 2019.

The experiment was conducted in a randomized blocks design, with four replicates and eight treatments, corresponding to soybean cultivation under the following cover crop straws: maize monoculture; maize intercropped with *Urochloa ruziziensis*; *U. ruziziensis* monoculture; sorghum intercropped with *U. ruziziensis*; sorghum monoculture; sunflower intercropped with *U. ruziziensis*; mix (millet + *Crotalaria spectabilis* + *U. ruziziensis*); and a fallow treatment (with the absence of a cover crop). The cover crop straws treatments originated from the 2018 and 2019 off-season crops. Prior to the implementation of the study, the area was covered by degraded pasture.

The evaluation of the feeding activity of the soil invertebrate fauna was carried out based on the ISO 18311 (ISO 2016), which standardizes the use of the bait-lamina as an indicator of soil quality under field conditions, and on Niva et al. (2021). The bait-lamina consisted of rods (blades) made of resistant plastic, being 120 mm long, 6 mm wide and 1 mm thick, with 16 holes of 2 mm in diameter, spaced 5 mm apart, manufactured using an outsourced industrial procedure based on Von Törne (1990) and Kratz (1998). A homogeneous mixture containing 70 % of microcrystalline cellulose, 27 % of oat flour and 3 % of activated carbon was used as the bait to be consumed by the soil fauna (ISO 2016, Niva et al. 2021). A total of 576 bait-laminae were used, which were divided into 72 bait-laminae per block, in three replicates, with 18 bait-blades in the total number of replicates. Six bait-laminae were arranged for each replicate, being inserted vertically into the soil in two rows, with 3 bait-laminae in each row, spaced 20 cm apart between the laminae and 20 cm between the rows (Figure 1).

The bait-laminae were inserted vertically into the soil at a depth of 8 cm, using a knife similar in size to the dimension of the lamina and a hammer to make a slit to expose the organic material to the soil organisms. The experiment was carried out from Dec. 21 (2018) to Mar. 01 (2019) in the first year, with 62 days of soybean planting, and from Apr. 12 to Dec. 17 (2019) in the second year, with 30 days of soybean planting. During this period, no pesticides were applied to the soybean crop, to avoid interfering with the results.

After 13 days of the laminae installation, they were removed from the ground, stored individually in aluminum foil and sent to the laboratory to evaluate the bait consumption in each lamina, using a magnifying glass to determine the feeding activity at

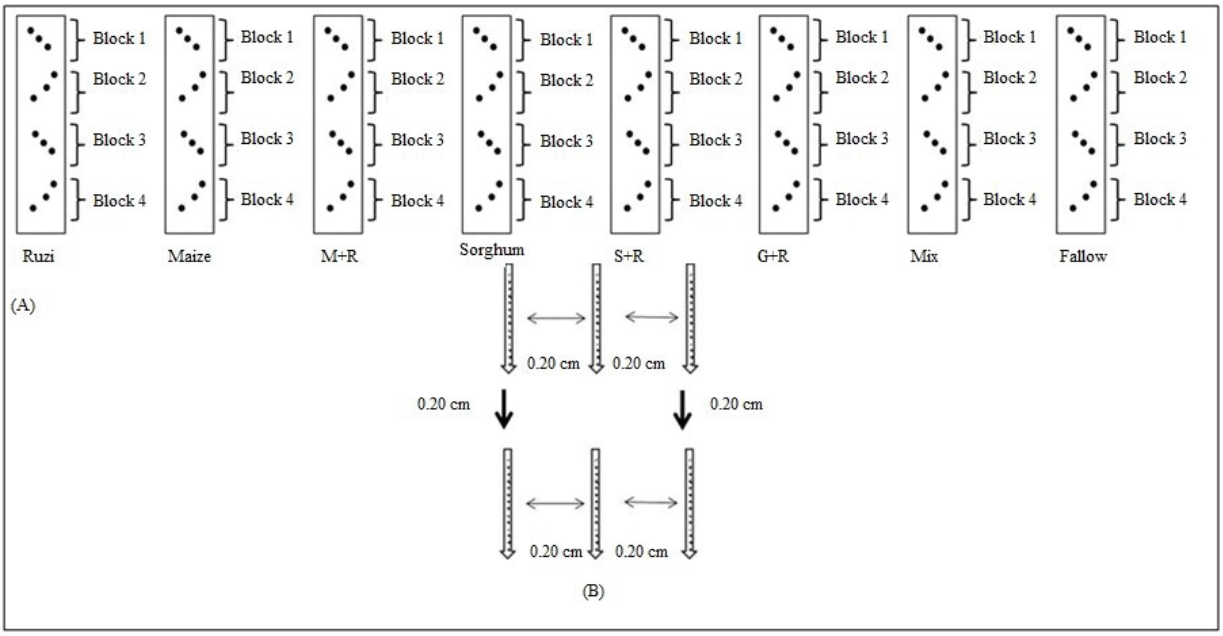

Figure 1. Scheme of the experimental area: A) division of randomized blocks with four replicates and eight treatments, with each treatment consisting of an area of 12 m wide x 150 m long; B) arrangement of the bait-laminae inserted vertically into the soil in two rows, with three bait-laminae in each row, spaced 20 cm apart between laminae and 20 cm apart between rows. Ruzi: *Urochloa ruziziensis*; M + R: maize intercropped with *U. ruziziensis*; S + R: sorghum intercropped with *U. ruziziensis*; G + R: sunflower intercropped with *U. ruziziensis*; mix: millet + *Crotalaria spectabilis* + *U. ruziziensis*.

the different depths. The perforations (consumption) of the 16 baits attached to each lamina were classified using the number 1 when consumption occurred and 0 when it did not occur. The results were expressed as percentage of baits consumed per centimeter of depth (ISO 2016, Niva et al. 2021).

To test the treatment effects and depth on the soil fauna community, mixed-effect (proc mixed) models were used in the SAS University edition software. The treatments and depths were considered as fixed effects, while the year was considered as the random effect. The data were checked for the presence of outliers and subsequently for residual normality (using the Shapiro Wilk test, with the 'shapiro.test' function of the R software) and variance homogeneity (using the Bartlett's test, with the 'bartlett.test' function of the R software). The consumption data were transformed using the arc sine. Means were compared by the Tukey test at 5 % of probability.

RESULTS AND DISCUSSION

In order for the bait-lamina test to be considered valid, at least 30 % of the holes containing bait material must have been consumed at one of the studied depths of the soil profile (ISO 2016). A consumption rate greater than 30 % was identified at various soil depths in all the tested treatments, making the test valid (Table 1).

The bait consumption rate expresses the feeding activity of soil fauna invertebrates. Regarding the analyzed effects, the following p values were observed: Treatment $P < 0.0001$; Year $P < 0.0001$; Treatment * Year $P < 0.0001$; Depth $P < 0.0001$; Treatment * Depth $P = 0.0489$; Year * Depth $P = 0.0384$; and Treatment * Year * Depth $P = 0.0222$. In almost all the treatments, a decrease in the feeding activity was observed at greater depths (Table 1). This behavior was expected, as most the organisms are found in the most superficial soil layer, where there is usually a greater biological activity for organic matter decomposition (Baretta et al. 2011, Brown et al. 2015) and a greater accumulation of organic matter favors the feeding activity. These results corroborate those found by Filzek et al. (2004), Casabé et al. (2007), Hamel et al. (2007), Podgaiski et al. (2011), Musso et al. (2014) and Niva et al. (2021), who verified a gradual decrease in food consumption at greater depths.

Table 1. Mean values in depth (1.0-8.0 cm) for the feeding activity of the soil fauna as a function of cover crop straws in integrated production systems, after 13 days of bait-lamina exposure.

Depth (cm)	Consumption (%)								MSE[7]
	Mix[2]	Sorghum	Maize	M + R[3]	G + R[4]	Ruzi[5]	S + R[6]	Fallow	
1	63.59 a[1]	57.78 ab	53.81 ab	53.20 ab	44.49 ab	41.48 ab	42.30 ab	37.06 b	5.73
2	48.45 a	47.04 a	43.62 a	44.73 a	39.15 a	31.39 a	37.09 a	31.62 a	5.24
3	41.23 a	31.11 a	34.59 a	34.99 a	41.29 a	24.97 a	30.47 a	28.92 a	4.57
4	40.13 a	25.59 a	34.81 a	31.97 a	35.67 a	29.66 a	28.14 a	28.57 a	4.97
5	37.86 a	23.84 a	28.59 a	29.78 a	31.24 a	24.85 a	23.74 a	27.50 a	5.00
6	35.60 a	22.60 a	28.16 a	23.69 a	27.28 a	24.43 a	23.06 a	31.94 a	4.37
7	38.97 a	20.73 a	32.08 a	24.35 a	26.36 a	30.12 a	23.68 a	36.91 a	4.30
8	41.32 ab	20.58 c	34.05 abc	30.48 bc	20.51 c	35.98 ab	18.96 c	45.76 a	3.91
Mean	43.39 a	31.16 c	36.21 ab	34.15 bc	33.25 bc	30.36 bc	28.43 c	33.54 bc	1.69

[1] Values followed by the same letter in the row do not differ from each other by the Tukey test ($p < 0.05$); [2] millet + *Crotalaria spectabilis* + *Urochloa ruziziensis*; [3] maize intercropped with *U. ruziziensis*; [4] sunflower intercropped with *U. ruziziensis*; [5] *U. ruziziensis*; [6] sorghum intercropped with *U. ruziziensis*; [7] mean standard error.

The mix treatment presented the highest consumption (63.59 %), when compared to the fallow treatment (37.06 %), at a depth of 1.0 cm; while the fallow treatment showed higher values at deeper layers, presenting an inverse behavior if compared to the mix treatment (Table 1). The fallow treatment is an area without planting, where the only vegetation for 8 months (before the soybean was planted) were herbs, usually without the ability to form sufficient soil cover. The present test was carried out when the soil was well exposed, with only a reduced amount of straw of herbaceous plants distributed sparsely and heterogeneously on the soil. This condition may have disadvantaged the habitat for invertebrates in the upper layers due to the lack of the 'food' resource (organic matter and microorganisms). In addition, the incidence of sunlight on the uncovered soil raised the temperature and dried the surface layers quickly, what may lead the invertebrates to seek a more favorable environment for their activity at deeper soil layers.

The mix treatment and the treatments with sorghum as cover crop showed the most pronounced decrease in the feeding activity at the depth up to 8 cm (Table 1). The mix treatment showed substantially higher values than all the other treatments at all depths, except for 8.0 cm, differing significantly only from the fallow treatment at the 1.0 cm layer (Table 1). This result suggests that the mix treatment was the most favorable among all the studied treatments to maintain the feeding activity of invertebrates in the upper soil layers. Podgaiski et al. (2011), who evaluated the feeding activity of soil invertebrates in grasslands of southern Brazil, observed a food consumption of 63.2 % at the depth of 0.5-2.0 cm, which are results similar to those found in the present research.

The layers at the depth of 5.0-10.0 cm are characterized by low permeability, generally presenting a hard structure, with limited porosity and little biological activity (Yagi et al. 2014). In the present study, depths of 2.0-7.0 cm presented a consumption without variation among the treatments (Table 1). Layers deeper than 7 cm were the ones that showed a significant reduction of feeding activity in the treatments with sorghum, sorghum intercropped with *U. ruziziensis* and sunflower intercropped with *U. ruziziensis*, suggesting that the different combinations of cover plants may influence the feeding activity at different soil depths.

At the depth of 8.0 cm, the fallow treatment presented the highest consumption (45.76 %; $p < 0.05$), when compared to the treatment with cover crop straws of sunflower intercropped with *U. ruziziensis*, sorghum and sorghum intercropped with *U. ruziziensis*, which presented consumptions of 20.51, 20.58 and 18.96 %, respectively (Table 1). The greater activity at deeper layers suggests that the fallow treatment did not favor the activity of the soil fauna in the surface layers probably due to the lack of organic matter and moisture.

According to Klimek et al. (2015), who observed an average fauna activity in soils of seven types of temperate forests ranging from 1.5 to 2.8 % of hole drilling per day of experiment (during 12 days of exposure), the result of the present study during the 13-day exposure is higher. Römbke et al. (2006), who studied the feeding activities of soil fauna in the Amazon, found a fauna activity of 6.8-17.5 % per day (in four days of exposure). The present study showed a consumption of 0.7-1.5 % per day (in 13 days), in the different treatments, while the consumption observed was 7.1 % in the reference area with native vegetation, which are values consistent with the aforementioned studies.

The invertebrates feeding activity reported in the present study suggests that the mix treatment was the most favorable for the maintenance of the biological activity of the soil fauna that contributes to organic matter decomposition, while the fallow treatment was the least favorable. The mix treatment consisted of millet, crotalaria and brachiaria. Birkhofer et al. (2011) found that the greater diversity of grasses and legumes increased the feeding activity and biomass of earthworms in a temperate climate region, what could explain the greater activity observed in areas with the use of mix. However, taking into consideration that the study was carried out in two years of cultivation of different cover crops, the effect of the different managements on the soil may be intensified in the coming years. Thus, it would be advisable to evaluate the feeding activity of the soil fauna in the studied area after a few more years, to verify the cumulative effect of the applied agricultural practices on the soil health, along with other biological, chemical and physical parameters.

CONCLUSIONS

1. The production systems under the straw cover crops sampled at the depth of 1.0 cm had a variation of 63.59-37.06 %, with a higher consumption for the mix, when compared to the fallow treatment;
2. At the depth of 2.0-7.0 cm, the consumption did not vary among the treatments;
3. For the depth of 8.0 cm, the fallow treatment presented the highest consumption (45.76 %), when compared to sunflower intercropped with *Urochloa ruziziensis* (20.51 %), sorghum (20.58 %) and sorghum intercropped with *U. ruziziensis* (18.96 %).

ACKNOWLEDGMENTS

To the Fundação de Amparo à Pesquisa do Estado de Goiás (FAPEG), for granting the scholarship to the first author; Grupo Associado de Pesquisa do Sudoeste Goiano (Gapes) and Embrapa Cerrados, for the technical support in conducting the experiment; and Instituto Federal de Educação, Ciência e Tecnologia Goiano, for the financial support for the publication of this study.

REFERENCES

BARETTA, D.; SANTOS, J. C. P.; SEGAT, J. C.; GEREMIA, E. V.; OLIVEIRA FILHO, L. C. I.; ALVES, M. V. *Fauna edáfica e qualidade do solo*. Viçosa: Sociedade Brasileira de Ciência do Solo, 2011.

BIRKHOFER, K., DIEKÖTTER, T.; BOCH, S.; FISCHER, M.; MÜLLER, J.; SOCHER, S.; WOLTERS, V. Soil fauna feeding activity in temperate grassland soils increases with legume and grass species richness. *Soil Biology and Biochemistry*, v. 43, n. 10, p. 2200-2207, 2011.

BROWN, G. G.; NIVA, C. C.; ZAGATTO, M. R. G.; FERREIRA, S. de A.; NADOLNY, H. S.; CARDOSO, G. B. X.; SANTOS, A.; MARTINEZ, G. de A.; PASINI, A.; BARTZ, M. L. C.; SAUTTER, K. D.; THOMAZINI, M. J.; BARETTA, D.; SILVA, E. da; ANTONIOLLI, Z. I.; DECAËNS, T.; LAVELLE, P. M.; SOUSA, J. P.; CARVALHO, F. *Biodiversidade da fauna do solo e sua contribuição para os serviços ambientais*. Brasília, DF: Embrapa, 2015.

CASABÉ, N.; PIOLA, L.; FUCHS, J.; ONETO, M. L.; PAMPARATO, L.; BASACK, S.; GIMÉNEZ, R.; MASSARO, R.; PAPAJ, C.; KESTEN, E. Ecotoxicological assessment of the effects of glyphosate and chlorpyrifos in an Argentine soya field. *Journal of Soils and Sediments*, v. 7, n. 4, p. 232-239, 2007.

CHERUBIN, M. R.; EITELWEIN, M. T.; FABBRIS, C.; WEIRICH, S. W.; SILVA, R. F.; SILVA, V. R.; BASSO, C. J. Qualidade física, química e biológica de um Latossolo com diferentes manejos e fertilizantes. *Revista Brasileira de Ciência do Solo*, v. 39, n. 2, p. 615-625, 2015.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA (Embrapa). *Manual de métodos de análise do solo*. 3. ed. Brasília, DF: Embrapa, 2017.

FERREIRA, C. R. P. C.; ANTONINO, A. C. D.; SAMPAIO, E. V. D. S. B.; CORREIA, K. G.; LIMA, J. R. D. S.; SOARES, W. D. A.; MENEZES, R. S. C. Soil CO_2 efflux measurements by alkali absorption and infrared gas analyzer in the Brazilian semiarid region. *Revista Brasileira de Ciência do Solo*, v. 42, e0160563, 2018.

FILZEK, P. D.; SPURGEON, D. J.; SVENDSEN, G. B. C.; HANKARD, P. K. Metal effects on soil invertebrate feeding: measurements using the bait lamina method. *Ecotoxicology*, v. 13, n. 8, p. 807-816, 2004.

HAMEL, C.; SCHELLENBERG, M. P.; HANSON, K. G.; WANG, H. Evaluation of the "bait-lamina test" to assess soil microfauna feeding activity in mixed grassland. *Applied Soil Ecology*, v. 36, n. 2-3, p. 199-204, 2007.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO). *ISO 18311*: soil quality: method for testing effects of soil contaminants on the feeding activity of soil dwelling organisms: bait-lamina test. Geneva: ISO, 2016.

KLIMEK, B.; NIKLIŃSKA, M.; JAŹWA, M.; CHODAK, M.; TARASEK, A. Application of the bait-lamina method to measure the feeding activity of soil fauna in temperate forests. *Polish Journal of Ecology*, v. 63, n. 3, p. 414-423, 2015.

KRATZ, W. The bait-lamina test. *Environmental Science and Pollution Research*, v. 5, n. 2, p. 94-96, 1998.

LOSS, A.; PEREIRA, M. G.; GIÁCOMO, S. G.; PERIN, A.; ANJOS, L. H. C. Agregação, carbono e nitrogênio em agregados do solo sob plantio direto com integração lavoura-pecuária. *Pesquisa Agropecuária Brasileira*, v. 46, n. 10, p. 1269-1276, 2011.

MENANDRO, L. M. S.; MORAES, L. O. de; BORGES, C. D.; CHERUBIN, M. R.; CASTIONI, G. A.; CARVALHO, J. L. N. Soil macrofauna responses to sugarcane straw removal for bioenergy production. *Bioenergy Research*, v. 12, n. 4, p. 944-957, 2019.

MUSSO, C.; MIRANDA, H. S.; SOARES, A. M. V. M.; LOUREIRO, S. Biological activity in *Cerrado* soils: evaluation of vegetation, fire and seasonality effects using the "bait-lamina test". *Plant and Soil*, v. 383, n. 1, p. 49-58, 2014.

NIVA, C. C.; PULROLNIK, K.; MARCHÃO, R. L.; CARVALHO, A.; MACHADO, C. T. de T.; PEREIRA, C. D.; MALAQUIAS, J. V.; VILELA, L.; RÖMBKE, J. *Método bait-lamina para a avaliação da atividade alimentar de invertebrados edáficos*: eficiência, limitações e adaptações para seu uso. Planaltina, DF: Embrapa Cerrados, 2021.

PARRON, L. M.; GARCIA, J. R.; OLIVEIRA, E. B. de; BROWN, G. G.; PRADO, R. B. *Serviços ambientais em sistemas agrícolas e florestais do bioma Mata Atlântica*. Brasília, DF: Embrapa, 2015.

PESSOTTO, M. D. F.; SANTANA, N. A.; JACQUES, R. J. S.; FREIBERG, J. A.; MACHADO, D. N.; PIAZZA, E. M.; ROSA NETO, L.; ANTONIOLLI, Z. I. Relação do uso do solo com a diversidade e a atividade da fauna edáfica. *Nativa*, v. 8, n. 3, p. 397-402, 2020.

PODGAISKI, L. R.; SILVEIRA, F. S.; MENDONÇA, M. Avaliação da atividade alimentar dos invertebrados de solo em campos do Sul do Brasil: bait-lamina test. *Entomo Brasilis*, v. 4, n. 3, p. 108-113, 2011.

RÖMBKE, J.; HOFER, H.; GARCIA, M. V. B.; MARTIUS, C. Feeding activities of soil organisms at four different forest sites in central Amazonia using the bait-lamina method. *Journal of Tropical Ecology*, v. 22, n. 3, p. 313-320, 2006.

SANTANA, N. A.; MORALES, C. A. S.; SILVA, D. A. A.; ANTONIOLLI, Z. I.; JACQUES, R. J. S. Soil biological, chemical, and physical properties after a wildfire event in a eucalyptus forest in the Pampa biome. *Revista Brasileira de Ciência do Solo*, v. 42, e0170199, 2018.

SANTOS, H. G.; JACOMINE, P. K. T.; ANJOS, L. H. C.; OLIVEIRA, V. A.; LUMBRERAS, J. F.; COELHO, M. R.; ALMEIDA, J. A.; ARAÚJO FILHO, J. C.; OLIVEIRA, J. B.; CUNHA, T. J. F. *Sistema brasileiro de classificação de solos*. 5. ed. Brasília, DF: Embrapa, 2018.

UNITED STATES DEPARTMENT OF AGRICULTURE (USDA). Soil Survey Staff. *Keys to soil taxonomy*. 12. ed. Washington, DC: USDA, 2014.

VON TÖRNE, E. Assessing feeding activities of soil-living animals: I. Bait-lamina tests. *Pedobiologia*, v. 34, n. 2, p. 89-101, 1990.

YAGI, R.; FIDALSKI, J.; TORMENA, C. A. A incorporação de calcário em sistema plantio direto consolidado reduz o estoque de carbono em macroagregados do solo. *Ciência Rural*, v. 44, n. 11, p. 1962-1965, 2014.