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Impact of no-tillage and straw on detritivorous arthropods on the surface on the soil in bean crops

Impacto do plantio direto e da palha em artrópodes detritívoros da superfície do solo na cultura do feijão

Impacto de la siembra directa y paja sobre artrópodos detritívoros en la superficie del suelo en cultivos de frijol

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Abstract
Detritivorous arthropods are essential because they participate in recycling organic matter, decomposing pesticides, improving soil properties, conserving water, and reducing problems with plant diseases. Practices such as no-till and straw on soils can affect soil properties and populations of detritivorous arthropods. Brazil is the largest producer and consumer of common beans (*Phaseolus vulgaris*). Thus, this work aimed to determine the impact of no-till and straw planting on detritivorous arthropods on the "surface over ground" in common bean crops. In this way, common beans were cultivated in tillage and no-till with and without straw on the soil. During cultivation, the density of detritivorous arthropods on the soil was monitored using a pitfall trap. Sixteen morphospecies of detritivorous arthropods were observed on the surface of the ground. No-tillage and straw did not affect the number of detritivorous arthropod species. The most abundant morphospecies was the Collembola Entomobryidae and *Hypogastrura* sp. and the Coleoptera Scarabaeidae and *Colopterus* spp. No-till and straw positively affected the abundance of detritivorous arthropods. Therefore, no-tillage and straw in bean crops provide conditions for increasing detritivorous arthropod populations, improving soil properties.
Keywords: *Phaseolus vulgaris*; Planting system; Collembola; Coleoptera; Abundance.

Resumo
Os artrópodes detritívoros são importantes por participarem da reciclagem da matéria orgânica, decomposição de pesticidas, melhoria das propriedades dos solos, conservação de água e redução das doenças nas plantas. Práticas como plantio direto e a palhada sobre os solos podem afetar as propriedades dos solos e as populações de artrópodes detritívoros. O Brasil é o maior produtor e consumidor de feijão comum (*Phaseolus vulgaris*). Assim, este trabalho

teve o objetivo de determinar o impacto do plantio direto e palhada sobre artrópodes detritívoros que vivem sobre o solo em lavoura de feijão comum. Para tanto, foi conduzida lavoura de feijão em plantio direto e convencional com ou sem palhada sobre o solo. Ao longo do cultivo foi monitorada a densidade dos artrópodes detritívoros sobre o solo usando armadilha do tipo pitfall. Foram observadas 16 morfoespécies de artrópodes detritívoros. O plantio direto e a palhada não afetaram o número de espécies de artrópodes detritívoros. As morfoespécies mais abundantes foram os Collembola Entomobryidae e *Hypogastrura* sp. e os Coleoptera Scarabaeidae e *Colopterus* spp. O plantio direto e a palhada afetaram positivamente a abundância de artrópodes detritívoros. Portanto, o plantio direto e a palhada nas lavouras de feijão propiciam condições para o aumento das populações de artrópodes detritívoros os quais melhoram as propriedades dos solos.
Palavras-chave: *Phaseolus vulgaris*; Sistema de plantio; Collembola; Coleoptera; Abundância.

Resumen

Los artrópodos detritívoros son importantes porque participan en el reciclaje de materia orgánica, descomposición de pesticidas, mejora de las propiedades del suelo, conservación del agua y reducción de enfermedades de las plantas. Prácticas como la labranza cero y la cobertura de suelos pueden afectar las propiedades del suelo y las poblaciones de artrópodos detritívoros. Brasil es el mayor productor y consumidor de frijol común (*Phaseolus vulgaris*). Por lo tanto, este trabajo tuvo como objetivo determinar el impacto de la siembra directa y la paja sobre los artrópodos detritívoros que viven en el suelo en cultivos de frijol común. Para ello, el cultivo del frijol se realizó bajo labranza cero y convencional con o sin paja en el suelo. Durante el cultivo, se monitoreó la densidad de artrópodos detritívoros en el suelo usando una trampa de caída. Se observaron dieciséis morfoespecies de artrópodos detritívoros. La labranza cero y la paja no afectaron el número de especies de artrópodos detritívoros. Las morfoespecies más abundantes fueron Collembola Entomobryidae e *Hypogastrura* sp. y los Coleoptera Scarabaeidae y *Colopterus* spp. La labranza cero y el mantillo afectaron positivamente la abundancia de artrópodos detritívoros. Por lo tanto, la labranza cero y la paja en los cultivos de frijol proporcionan condiciones para aumentar las poblaciones de artrópodos detritívoros, que mejoran las propiedades del suelo.
Palabras clave: *Phaseolus vulgaris*; Sistema de siembra; Colémbolo; Coleópteros; Abundancia.

1. Introduction

Detritivorous arthropods have essential functions in agroecosystems. They participate in recycling organic matter, decomposing pesticides, improving soil properties, conserving water, and reducing problems with pathogens that cause plant diseases (Zaller et al., 2016; Meyer-Wolfarth et al., 2017; Raghuraman & Mishra, 2017; Wang et al., 2017; Innocenti & Sabatini, 2018; Gruss et al., 2019). Thus, it is important to adopt practices that increase the abundance and diversity of detritivorous arthropods in soils (House & Stinner, 1983; Seastedt & Crossley Jr, 1984; Pereira et al., 2010).

Pitfall traps are among the sampling techniques for evaluating the populations of detritivorous arthropods on the soil surface. These traps are low-cost and easy to use, making it possible to capture arthropods found on the soil surface (House & Stinner, 1983; Prasifka et al., 2007; Brown & Matthews, 2016).

Beans belong to several species of the Fabaceae family, and they are used in human nutrition as a source of proteins, carbohydrates, vitamins (mainly B complex), minerals (iron, calcium, potassium, and phosphorus), and fiber (Popescu & Golubev, 2012; Carneiro et al., 2015). In 2020 the world production of beans was 27.55 million tons, and these crops occupied 34.80 million hectares (FAO, 2020). In Brazil, the main bean produced is the *Phaseolus vulgaris* L. species, known as common beans. Brazil is the largest producer and consumer of common beans (Carneiro et al., 2015).

Among the practices used in common bean crops are the use of no-till and straw on the soils (Galvão et al., 2017). The no-till consists of planting without turning the soil using suitable machines for its realization. Using this planting system allows for greater moisture retention in the soil, reduction of erosion, and improvement of the physicochemical conditions of the soils (Altmann, 2010). In addition, no-till can affect the populations of organisms that live on the surface and interior of soils (Pereira et al., 2010). The presence of straw in the soil protects this natural resource, reduces erosion, positively affects the soil's physical, chemical, and biological characteristics, and contributes to retaining moisture (Altmann, 2010).

Common bean crops can be managed after corn (*Zea mays* L.). Thus, the straw left by the previous maize cultivation serves to provide straw that remains on the surface of the soil where the common bean crop will be carried out. Thus, this work

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aimed to determine the impact of no-tillage and straw on detritivorous arthropods on the soil surface in common bean crops.

2. Methodology

This study was carried out at the Universidade Federal de Viçosa experimental station in Coimbra (20º51'30"S, 42º48'30"W and 716 m altitude), state of Minas Gerais, Brazil. The climate of this place is classified as high-altitude tropical with an average annual temperature of 19ºC and rainfall between 1300 and 1400 mm per year, and it has clayey soil classified as Cambic Red-Yellow Podzolic (Vieira et al., 2011).

The factors under study were the planting system (tillage or no-till) and the straw on the soil. In these places, corn was already for more than ten years in tillage and no-till. In the experimental units with straw, maize was grown for grain production previously. Thus, in these areas, there was a straw over the soil. In the repetitions without straw, corn was grown for silage production previously. Therefore, the whole aerial part of the maize plants was harvested during the maize harvest without leaving any straw on the soil (Galvão et al., 2017).

The cultivar midnight (from the black commercial group) was used in a spacing of 0.45 m between rows and 10 seeds per meter of row and the planting was carried out at the end of April. Normal cultivation practices were used in the field (Carneiro et al., 2015). The experiment was installed in randomized blocks with five replications. Each experimental unit was 5 m long by 5.4 m wide, and each had 12 rows of bean plants.

In the evaluation of the populations of detritivorous arthropods, pitfall traps were used according to Hohbein and Conway (2018). These traps were 10 cm in diameter. The traps were installed when the bean plants were 20, 28, 35, 43 and 84 days after planting. The traps remained for 48 hours, capturing the detritivorous arthropods from the soil surface. The captured arthropods were placed in a 250 mL plastic bottle containing 70% ethanol and transported to the laboratory. In the laboratory, detritivorous arthropods were separated into morphospecies. The density of morphospecies in each experimental unit and evaluation date was evaluated. Collembola morphospecies were identified by Dr. Elisiana Oliveira from the Instituto Nacional de Pesquisa da Amazônia de Manaus (INPA). Dr. Antonio Domingos Brescovit identified the Coleoptera morphospecies from the Instituto Butantan (São Paulo, SP) for identifying the Coleoptera. To evaluate the impact of no-till and straw on detritivorous arthropods on the soil surface in bean crops, a histogram of the number of arthropod morphospecies in each treatment was made (Pimentel & Wheeler Jr, 1973).

The frequency of occurrence of each morphospecies throughout the experiment was calculated to evaluate the impact of treatments on the abundance of detritivorous arthropods. In this calculation, formula (1) was used.

$$(1) \quad F = (100 \times Ni) \div Tn$$

where: F = frequency (%), Ni = number of evaluations (number of traps and evaluation dates) in which morphospecies was collected and Tn = total number of evaluations (100 observations).

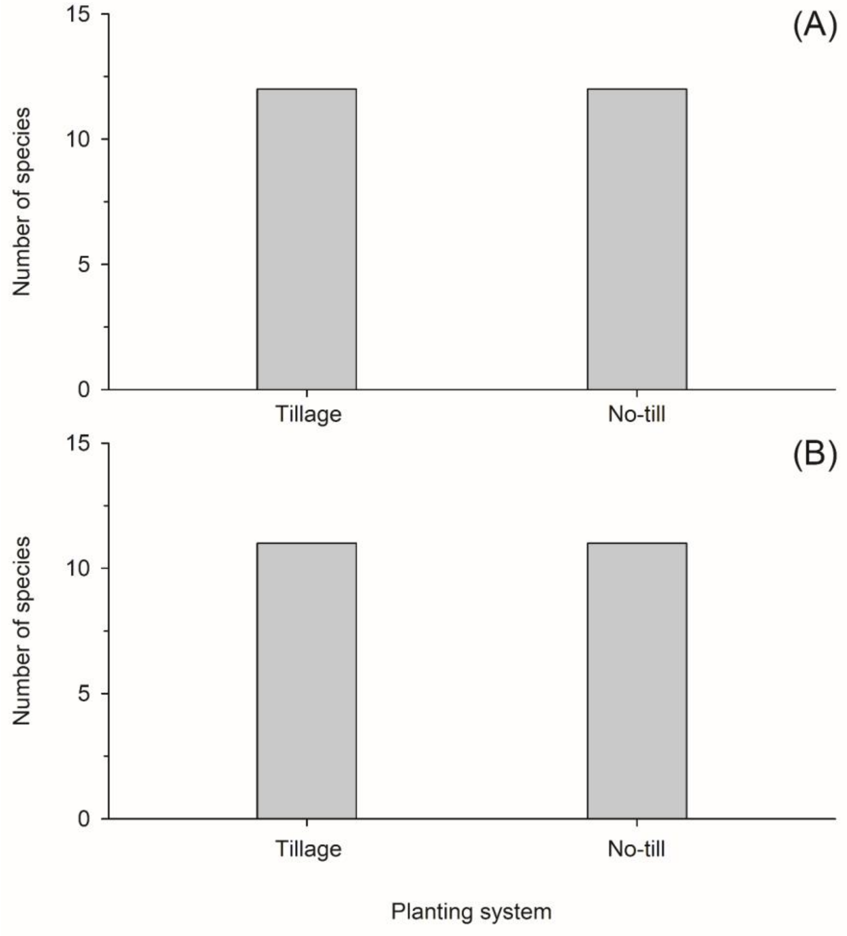
Arthropod morphospecies with a minimum frequency of occurrence of 10% were selected. This was done because using rare species generated errors in these analyses (Badji et al., 2004; Pereira et al., 2010). The densities (mean ± standard error) of each most abundant morphospecies (frequency ≥ 10%) were calculated. Means were considered different when there was no overlap in the mean ± standard error range. Next, the abundance data of the most frequent morphospecies were subjected to multivariate analysis of canonical variables using the SAS program (SAS Institute, 2009). In this analysis, the appropriate morphospecies were initially selected to represent the variation in the abundance of detritivorous arthropods. In this selection process, the data were analyzed for maximum explained variance. The morphospecies whose densities presented significant F ($P < 0.05$) in the covariance and square canonical correlation were selected in this analysis. Subsequently, the coefficients of the canonical axes of the impact of no-till and straw on detritivorous arthropods living on the ground in bean crops were calculated (Badji et al., 2004; Pereira et al., 2010). Next, graphs were made of the variation in densities (mean ±

standard error) of the selected arthropod morphospecies as a function of the age of the common bean plants in each treatment.

3. Results and Discussion

Sixteen morphospecies of detritivorous arthropods were observed in all treatments. These arthropods were Collembola and insects of the order Coleoptera. It was observed that the number of species of detritivorous arthropods in bean crops in no-till and tillage was the same. Also, the number of detritivorous arthropods species in bean crops with and without straw was the same (Figure 1). Therefore, no-till and straw did not affect the number of detritivorous arthropod species on the soil surface. This happened, possibly because these different conditions did not affect the occurrence of these species. Thus, in the situations studied, the soil in the crops must have had minimum conditions for these arthropods' survival, development, growth, and reproduction (Chen & Wise, 1999; Pereira et al., 2017; Gonçalves et al., 2021).

Figure 1. Species richness (species per treatment) of detritivorous arthropods on the soil surface in common bean crops in tillage and no-till (A) with straw and (B) without straw.

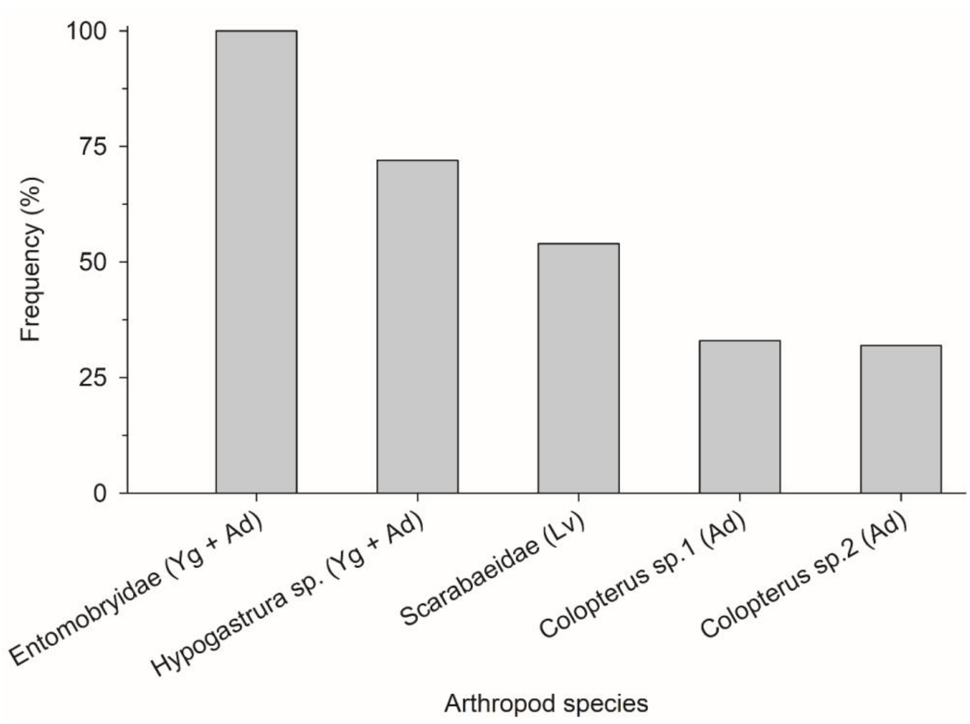


Source: Authors.

Five morphospecies had a minimum frequency of occurrence of 10%, and they were used to assess the impact of no-till and straw on the abundance of detritivorous arthropods living on the soil surface in common bean crops (Badji et al., 2004; Pereira et al., 2010). Two of these morphospecies were Collembola, and three other morphospecies were insects. The Collembola observed were Entomobryidae and *Hypogastrura* sp. (Hypogastruridae). The insects observed were of the order

Coleoptera, and they were larvae of Scarabaeidae, adults of *Colopterus* sp.1, and adults of *Colopterus* sp.2 (Nitidulidae). Collembola morphospecies showed a higher frequency of occurrence than insect morphospecies. The decreasing order of frequency of occurrence was Entomobryidae > *Hypogastrura* sp. > Scarabaeidae larvae > *Colopterus* sp.1 ≅ *Colopterus* sp.2 (Figure 2). Carpio et al. (2019), Pereira et al. (2018), Livia-Tacza and Sánchez (2020) observed Entomobryidae in soils in olive groves, soybean and sweetpotato, respectively. Ramezani and Mossadegh (2017), Pereira et al. (2018), and Chang et al. (2020) observed *Hypogastrura* sp. in soils in tomato, soybean, and corn crops, respectively. Also, Rondon et al. (2011), Bouchard and Hébert (2016). Frizzas et al. (2017) observed *Hypogastrura* sp. in soils in strawberry, forest, and corn crops, respectively.

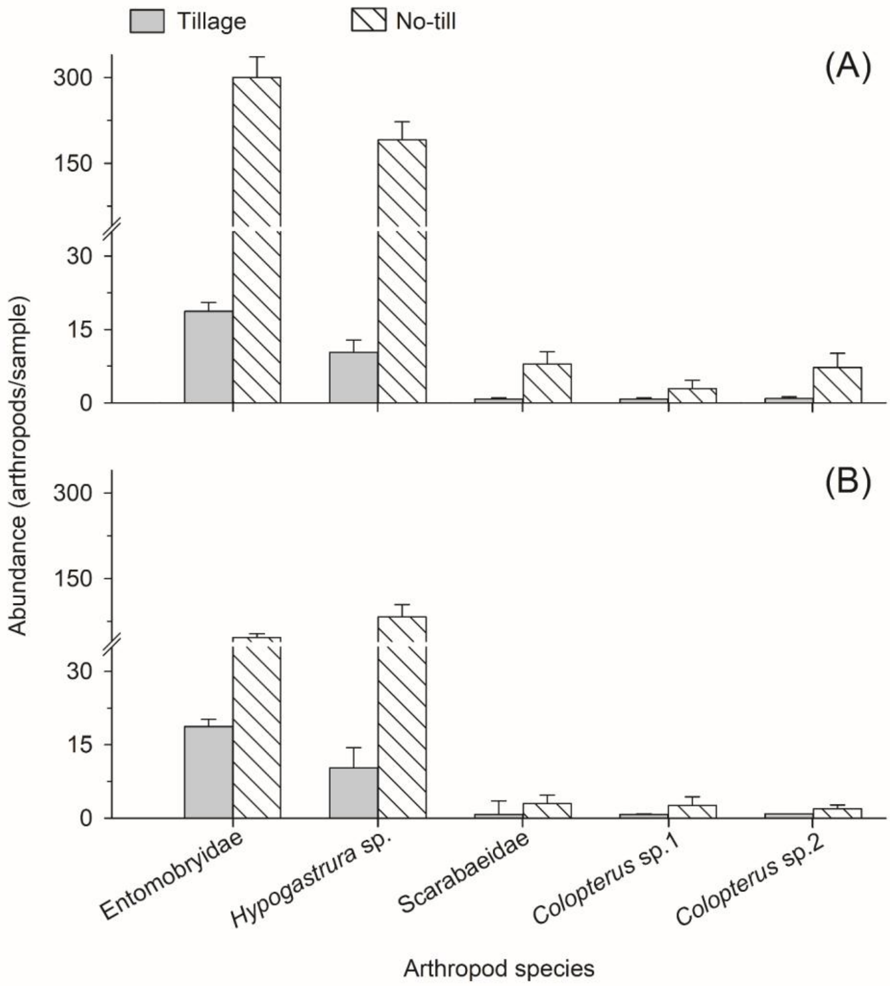
Figure 2. Frequency of detritivorous arthropod species on the soil surface in common bean crops in tillage and no-till with straw and without straw.



Source: Authors.

The no-till effect was observed in the abundance of detritivorous insects on the soil in the bean crop. However, no straw effect was observed on the soil abundance of detritivorous arthropods. It was found that the densities of the five most abundant morphospecies were higher on the soil surface of no-till crops than in tillage crops (Figure 3). Therefore, tillage had a negative effect on reducing the abundance of detritivorous arthropods on the soil. These arthropods play an important role in soils by recycling organic matter, decomposing pesticides, improving soil physicochemical properties, conserving water, and reducing problems with pathogens that cause plant diseases (Zaller et al., 2016; Meyer-Wolfarth et al., 2017; Raghuraman & Mishra, 2017; Wang et al., 2017; Innocenti & Sabatini, 2018; Gruss et al., 2019).

Figure 3. Abundance (mean ± standard error) of detritivorous arthropod species on the soil surface in common bean crops in tillage, no-till (A) with straw, and (B) without straw.



Source: Authors.

The morphospecies Entomobryidae and *Hypogastrura* sp. were selected by the STEPWISE method to be used in the analysis of canonical variables on the impact of no-till and straw on detritivorous arthropods that live on the soil surface in common bean crops (Table 1). This was due to the fact that these two arthropod morphospecies were the most frequent and abundant on the soil surface in bean crops. In this context, it has been found that the most abundant and frequent species are generally those that best represent the variation in the community of organisms (Legendre & Birks, 2012; Mereta et al., 2012).

In the analysis of covariance for the selection of morphospecies to be used in the analysis of canonical variables to represent the arthropod community, it was found that the abundances of Entomobryidae (F = 57.21 and $P < 0.0001$) and *Hypogastrura* sp. (F = 5.87 and $P = 0.001$) showed significant effects ($P < 0.05$). Also, the square canonical correlation of the abundances of Entomobryidae (r = 0.21 and $P < 0.0001$) and *Hypogastrura* sp. (r = 0.42 and $P < 0.0001$) were significant ($P < 0.05$). Furthermore, the variation in the abundances of Entomobryidae (R2 = 0.64) and *Hypogastrura* sp. (R2 = 0.16) showed the highest coefficients of determination (R2) which demonstrates that these two morphospecies are suitable to represent the variation that occurred in the community of detritivorous arthropods on the soils of bean crops in this work. The cumulative coefficient of determination of the variation of abundances in relation to the total abundance of the detritivorous arthropod community was 0.76 (Table 1). This fact indicates that these two morphospecies explained 76% of the variation in the total abundance of the detritivorous arthropod community on bean crop soils (Legendre et al., 2011; Gkisakis et al. 2016; Sannigrahi et al., 2020).

Table 1. Summary of the analysis of the selection of arthropod species by the STEPWISE method to be used in the analysis of canonical variables on the impact of no-till and straw on detritivorous arthropods on the soil surface in common bean crops.

Arthropod morphospecies	R^2	Covariance analysis		Square Canonical correlation	
		F	*P*	Mean	*P*
Entomobryidae	0.64	57.21	<0.0001	0.21	<0.0001
Hypogastrura sp.	0.16	5.87	0.001	0.42	<0.0001

Source: Authors.

Two canonical axes were used in the model used to represent variation in the abundance of the arthropod community on the soil of bean crops. *Hypogastrura* sp. was the morphospecies with the highest coefficient (0.845) in the canonical axis 1. Entomobryidae was the morphospecies with the highest coefficient (0.665) in the canonical axis 2 (Table 2). Therefore, these two morphospecies showed great representation to characterize the community of detritivorous arthropods on the soil surface in bean crops, since they presented the highest coefficients in the two canonical axes of the model (Legendre & Birks, 2012).

Table 2. Coefficients of the canonical axes of the impact of no-till and straw on detritivorous arthropods on the surface of the ground in common bean crops.

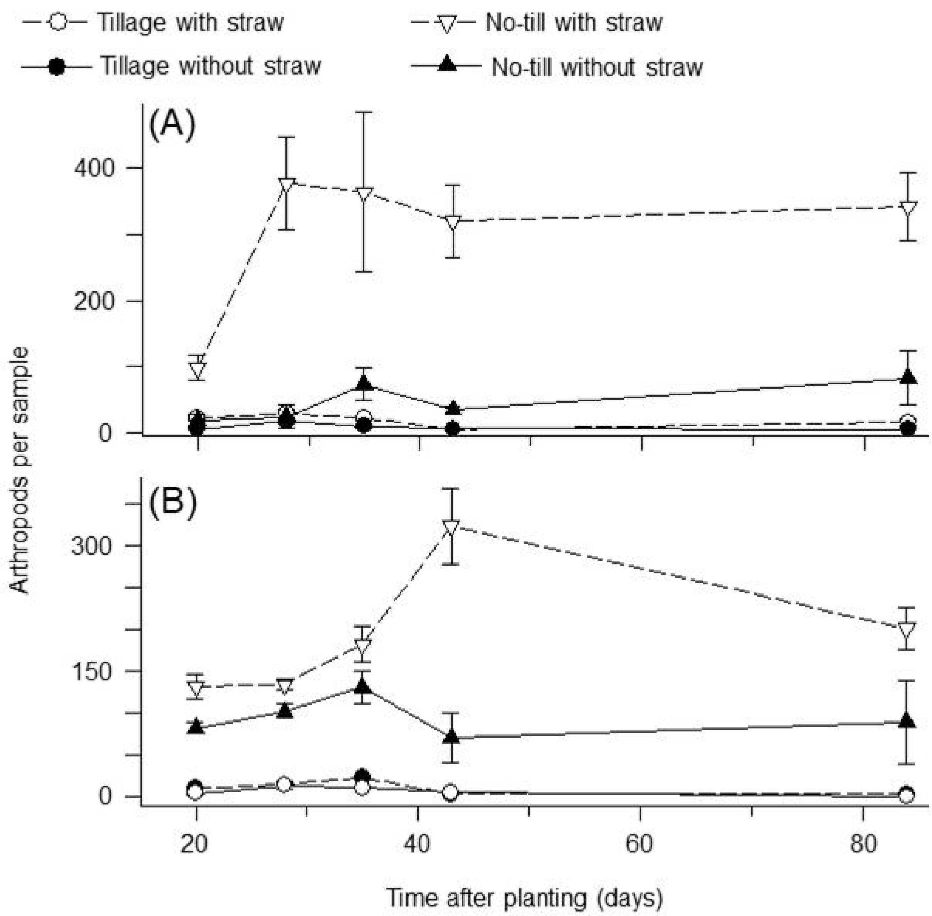
Arthropod morphospecies	Canonical Axes	
	1	2
Entomobryidae	-0.302	0.845
Hypogastrura sp.	0.665	0.395

Source: Authors.

Entomobryidae abundance was higher in no-till crops than in tillage crops. In no-till crops, the abundance of Entomobryidae was higher when there was straw on the soil. In no-till crops, the abundance of Entomobryidae increased even when the bean plants were 20 to 30 days after planting. From then on, these populations remained high until the end of cultivation. In tillage, the abundance of Entomobryidae was low (less than 5 collembola per sample) and it varied little during bean cultivation (Figure 4A).

The abundance of *Hypogastrura* sp. was higher in no-till crops than in tillage crops. In no-till crops, the abundance of *Hypogastrura* sp. was greater when straw was on the ground. In no-till crops, the abundance of *Hypogastrura* sp. reached its maximum when the bean plants were halfway through the cultivation period, from then on, there was a decrease in the abundance of this Collembola. In tillage, the abundance of *Hypogastrura* sp. was low (less than 5 collembola per sample), and varied little throughout the cultivation (Figure 4B).

Figure 4. Density (mean ± standard error) of detritivorous arthropods (A) Entomobryidae (Collembola) and (B) *Hypogastrura* sp. (Collembola: Hypogastruridae) on the surface of the soil during the conduction of common bean crop in tillage, no-till, with straw and without straw.



Source: Authors.

Therefore, no-till and straw on the soil positively affected the abundance of Collembola on the soil surface in bean crops. This fact occurred possibly because the soil disturbance in tillage crops negatively affects the Collembola populations causing their death due to the mechanical impact of this practice as well as it affects the reduction of food resources for these arthropods (Meli et al., 2014; Coulibaly et al. al., 2017; Müller et al., 2022). Straw on the soil favorably affected the abundance of Collembola on the soil of bean crops, possibly because it serves as a shelter and food and provides an adequate micro-habitat for these arthropods (Andrén & Schnürer, 1985; Dittmer & Schrader, 2000; Mint, 2012).

4. Conclusion

No-till and straw increase the abundance of detritivorous arthropods, especially Collembola, on the soil surface in common bean crops. The main groups of Collembola on these soils are Entomobryidae and Hypogastrura sp. These arthropods are involved in recycling organic matter, decomposing pesticides, improving soil properties, conserving water, and reducing problems with pathogens that cause plant diseases. Therefore, the results of this study will contribute to future research about the monitoring of detritivorous arthropods on the soil.

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References

Altmann, N. (2010*). Plantio direto no cerrado: 25 anos acreditando no sistema*. Editora Aldeia Norte

Andrén, O., & Schnürer, J. (1985). Barley straw decomposition with varied levels of microbial grazing by *Folsomia fimetaria* (L.) (Collembola, Isotomidae). *Oecologia, 68*(1), 57-62.

Badji, C. A., Guedes, R. N. C., Silva, A. A., & Araújo, R. A. (2004). Impact of deltamethrin on arthropods in maize under conventional and no-tillage cultivation. *Crop Protection, 23*(11), 1031-1039. https://doi.org/10.1016/j.cropro.2004.03.003

Bouchard, M., & Hébert, C. (2016). Beetle community response to residual forest patch size in managed boreal forest landscapes: Feeding habits matter. *Forest Ecology and Management, 368*, 63-70. https://doi.org/10.1016/j.foreco.2016.02.029

Brown, G. R., & Matthews, I. M. (2016). A review of extensive variation in the design of pitfall traps and a proposal for a standard pitfall trap design for monitoring ground-active arthropod biodiversity. *Ecology and Evolution, 6*(12), 3953-3964. http://dx.doi.org/10.1002/ece3.2176

Carneiro J. E., Paula Jr, T. P., & Borém, A. (2015). *Feijão do plantio à colheita*. Editora UFV.

Carpio, A. J., Castro, J., & Tortosa, F. S. (2019). Arthropod biodiversity in olive groves under two soil management systems: presence versus absence of herbaceous cover crop. *Agricultural and Forest Entomology, 21*(1), 58-68. http://dx.doi.org/10.1111/afe.12303

Chang, L., Song, X., Wang, B., Wu, D., & Reddy, G. V. (2020). Effect of Bt Corn (Bt 38) Cultivation on Community Structure of Collembola. *Annals of the Entomological Society of America, 113*(1), 1-5. http://dx.doi.org/10.1093/aesa/saz038

Chen, B., & Wise, D. H. (1999). Bottom-up limitation of predaceous arthropods in a detritus-based terrestrial food web. *Ecology, 80(3), 761-772*. https://doi.org/10.1890/0012-9658(1999)080[0761:BULOPA]2.0.CO;2

Coulibaly, S. F., Coudrain, V., Hedde, M., Brunet, N., Mary, B., Recous, S., & Chauvat, M. (2017). Effect of different crop management practices on soil Collembola assemblages: A 4-year follow-up. *Applied Soil Ecology, 119*, 354-366. https://doi.org/10.1016/j.apsoil.2017.06.013

Dittmer, S., & Schrader, S. (2000). Longterm effects of soil compaction and tillage on Collembola and straw decomposition in arable soil. *Pedobiologia, 44*(3-4), 527-538. https://doi.org/10.1078/S0031-4056(04)70069-4

FAO - Food and Agriculture Organization of the United Nations. (2020). *FAOSTAT: Statistics database*. http://www.fao.org/faostat/en/#data/QC

Frizzas, M. R., Oliveira, C. M. D., & Omoto, C. (2017). Diversity of insects under the effect of Bt maize and insecticides. *Arquivos do Instituto Biológico, 84,* e0062015. https://doi.org/10.1590/1808-1657000062015

Galvão J. C. C., Borém, A., & Pimentel, M. A. (2017). *Milho do plantio à colheita*. (2ª ed.) Editora UFV.

Gkisakis, V., Volakakis, N., Kollaros, D., Bàrberi, P., & Kabourakis, E. M. (2016). Soil arthropod community in the olive agroecosystem: Determined by environment and farming practices in different management systems and agroecological zones. *Agriculture, Ecosystems & Environment, 218,* 178-189. https://doi.org/10.1016/j.agee.2015.11.026

Gonçalves, F., Carlos, C., Crespo, L., Zina, V., Oliveira, A., Salvação, J., Pereira J. A., & Torres, L. (2021). Soil Arthropods in the douro demarcated region vineyards: general characteristics and ecosystem services provided. *Sustainability, 13*(14), 7837. https://doi.org/10.3390/su13147837

Gruss, I., Twardowski, J. P., Latawiec, A., Królczyk, J., & Medyńska-Juraszek, A. (2019). The effect of biochar used as soil amendment on morphological diversity of Collembola. *Sustainability, 11*(18), 5126. http://dx.doi.org/10.3390/su11185126

Hohbein, R. R., & Conway, C. J. (2018). Pitfall traps: A review of methods for estimating arthropod abundance. *Wildlife Society Bulletin, 42*(4), 597-606. http://dx.doi.org/10.1002/wsb.928

House, G. J., & Stinner, B. R. (1983). Arthropods in no-tillage soybean agroecosystems: community composition and ecosystem interactions. *Environmental Management, 7*(1), 23-28. https://doi.org/10.1007/s41348-017-0111-y

Innocenti, G., & Sabatini, M. A. (2018). Collembola and plant pathogenic, antagonistic and arbuscular mycorrhizal fungi: A review. *Bulletin of Insectology, 71*(1), 71-76.

Legendre, P., Oksanen, J., & Ter Braak, C. J. (2011). Testing the significance of canonical axes in redundancy analysis. *Methods in Ecology and Evolution, 2*(3), 269-277. http://dx.doi.org/10.1111/j.2041-210X.2010.00078.x

Legendre, P., & Birks, H. J. B. (2012). From classical to canonical ordination. In: *Tracking environmental change using lake sediments* (pp. 201-248).

Springer, Dordrecht.

Livia-Tacza, C., & Sánchez, G. (2020). Soil arthropods associated with sweetpotato crop (Ipomoea batata L.) in La Molina, Lima, Peru. *Peruvian Journal of Agronomy, 4*(1), 1-9. http://dx.doi.org/10.21704/pja.v4i1.1438

Meli, M., Palmqvist, A., & Forbes, V. E. (2014). Implications of interacting microscale habitat heterogeneity and disturbance events on Folsomia candida (Collembola) population dynamics: a modeling approach. *Environmental Toxicology and Chemistry, 33*(7), 1508-1516. http://dx.doi.org/10.1002/etc.2552

Mereta, S. T., Boets, P., Bayih, A. A., Malu, A., Ephrem, Z., Sisay, A., Endale H., Yitbarek, M., Jemal, A., Meesterc, L., & Goethals, P. L. M. (2012). Analysis of environmental factors determining the abundance and diversity of macroinvertebrate taxa in natural wetlands of Southwest Ethiopia. *Ecological Informatics, 7*(1), 52-61. https://doi.org/10.1016/j.ecoinf.2011.11.005

Meyer-Wolfarth, F., Schrader, S., Oldenburg, E., Weinert, J., & Brunotte, J. (2017). Collembolans and soil nematodes as biological regulators of the plant pathogen *Fusarium culmorum*. *Journal of Plant Diseases and Protection, 124*(5), 493-498.

Mint, C. (2012). Soil fauna diversity-function, soil degradation, biological indices, soil restoration. In*: Biodiversity conservation and utilization in a diverse world* (pp. 59-94). BoD–Books on Demand.

Müller, P., Neuhoff, D., Nabel, M., Schiffers, K., & Döring, T. F. (2022). Tillage effects on ground beetles in temperate climates: a review. *Agronomy for Sustainable Development, 42*(4), 1-20. https://doi.org/10.1007/s13593-022-00803-6

Pereira, J. L., Picanço, M. C., Pereira, E. J. G., Silva, A. A., Jakelaitis, A., Pereira, R. R., & Xavier, V. M. (2010). Influence of crop management practices on bean foliage arthropods. *Bulletin of Entomological Research, 100*(6), 679-688. http://dx.doi.org/10.1017/S0007485310000039

Pereira J. L., Moreira, M. D., Santana Jr., P. A., Lopes, M. C., Ramos R. S., Silva A. A., & Picanço, M. C. (2017). Impact of the cultivation systems and straw on the soil surface on the edaphic entomofauna in common bean crops. *Australian Journal of Basic and Applied Sciences, 11*(2), 6-15.

Pereira, J. L., Lopes, M. C., Parish, J. B., Silva, A. A., & Picanço, M. C. (2018). Impact of RR soybeans and glyphosate on the community of soil surface arthropods. *Planta Daninha, 36*, e018171324. http://dx.doi.org/10.1590/S0100-83582018360100071

Pimentel, D., & Wheeler Jr, A. G. (1973). Species and diversity of arthropods in the alfalfa community. *Environmental Entomology, 2*(4), 659-668. https://doi.org/10.1093/ee/2.4.659

Popescu, E., & Golubev I. (2012). *Beans: Nutrition, consumption and health*. Nova Science Pub Inc.

Prasifka, J. R., Lopez, M. D., Hellmich, R. L., Lewis, L. C., & Dively, G. P. (2007). Comparison of pitfall traps and litter bags for sampling ground-dwelling arthropods. *Journal of Applied Entomology, 131*(2), 115-120. http://dx.doi.org/10.1111/j.1439-0418.2006.01141.x

Raghuraman, M., & Mishra, V. K. (2017). Collembola as indicator of soil health. *Journal of Insect Science (Ludhiana), 30*(2), 166-170.

Ramezani, L., & Mossadegh, M. S. (2017). The effect of cropping on diversity and density of springtails (Hexapoda: Collembola) in Khuzestan province, Southwest of Iran. *IAU Entomological Research Journal, 8(4), 301-307.*

Rondon, S. I., Price, J. F., Cantliffe, D. J., & Renkema, J. M. (2011). *Sap beetle (Coleoptera: Nitidulidae) management in strawberries*. Gainesville: University of Florida.

Sannigrahi, S., Zhang, Q., Pilla, F., Joshi, P. K., Basu, B., Keesstra, S., & Sen, S. (2020). Responses of ecosystem services to natural and anthropogenic forcings: A spatial regression based assessment in the world's largest mangrove ecosystem. *Science of the Total Environment, 715, 137004.* https://doi.org/10.1016/j.scitotenv.2020.137004

SAS Institute. (2009). *SAS/STAT user's guide, vol 9*. SAS, Cary.

Seastedt, T. R., &Crossley Jr, D. A. (1984). The influence of arthropods on ecosystems. *Bioscience, 34*(3), 157-161. https://doi.org/10.2307/1309750

Vieira, R. F., Paula Jr, T. J., Jacob, L. L., Lehner, M. S., Santos, J. D. (2011). Desempenho de genótipos de feijão-mungo-verde semeados no inverno na Zona da Mata de Minas Gerais. *Revista Ceres, 58,* 402-405. https://doi.org/10.1590/S0034-737X2011000300022

Wang, M., Zhang, W., Xia, H., Huang, J., Wu, Z., & Xu, G. (2017). Effect of Collembola on mineralization of litter and soil organic matter. *Biology and Fertility of Soils, 53(5), 563-571*. https://doi.org/10.1007/s00374-017-

Zaller, J. G., König, N., Tiefenbacher, A., Muraoka, Y., Querner, P., Ratzenböck, A., Bonkowski, M., & Koller, R. (2016). Pesticide seed dressings can affect the activity of various soil organisms and reduce decomposition of plant material. *BMC ecology, 16*(1), 1-11. https://doi.org/10.1186/s12898-016-0092-x