EDAPHIC MACROFAUNA IN AREAS CULTIVATED WITH IRRIGATED BRASSICA UNDER NO-TILLAGE SYSTEM

Áureo Ribeiro Neto 1
Sandra Santana de Lima²
Ricardo Antônio Barbos Robson Thomaz Thuler³
Dinamar Márcia da Silva Vieira⁴
Arcângelo Loss⁵
Iara Uliana Moraes Sampaio⁶
Virgínia Oliveira Coelho⁷
José Luiz Rodrigues Torres⁸

ABSTRACT

Objective: Quantify and qualify the soil macrofauna present in areas cultivated with brassicas under the No-till system vegetable (NTSV) in different phases.

Method/design/approach: The study was conducted in three different areas: 1-NTSV with one year (NTSV1), 2-NTSV with three years (NTSV3), 3-Native Forest (In natural regeneration for 20 years (NF20)); At depths: 0-10; 10-20 and 20-30 cm, with 5 repetitions. Litter was collected in an area of 0.50x0.50 cm and soil samples were collected with an iron square measuring 25x25x30 cm in each plot, where the number of individuals (ind m⁻²) was quantified and the total richness and diversity and equitability indexes of the macrofauna were qualified.

Result and conclusion: The management in areas NTSV1, NTSV3 and NF20 favored the development of the population of the Formicidae and Isoptera groups; The NTSV3 area at a depth of 20 to 30 cm provided the best conditions for the highest relative frequency of the Oligochaeta group.

Research implications: The assessment of vertical distribution favored a broader knowledge of the macrofauna community in the systems; The adoption time of the one- or three-cycle no-tillage system did not affect the density and diversity of macrofauna.

Originality/value: Most studies soil macrofauna have been carried out in areas under conventional or no-tillage of grains or in forests, few studies are carried out in areas with irrigated vegetables, where processes involving organic matter reach be three times faster, where the diversity of this macrofauna is higher and needs to be evaluated.

1 Instituto Federal do Triângulo Mineiro Campus Uberaba, Uberaba, Minas Gerais, Brazil. E-mail: netoaur0@hotmail.com Orcid: https://orcid.org/0000-0003-278-6396
2 Universidade Federal Rural do Rio de Janeiro, Seropédica, Rio de Janeiro, Brazil. E-mail: sandraslimao@gmail.com Orcid: https://orcid.org/0000-0003-3599-8344
3 Instituto Federal do Triângulo Mineiro Campus Uberaba, Uberaba, Minas Gerais, Brazil. E-mail: rthuler@iftm.edu.br Orcid: https://orcid.org/0000-0002-1512-7851
4 Universidade Federal de Uberlândia, Uberlândia, Minas Gerais, Brazil. E-mail: marcinha_0202@hotmail.com Orcid: https://orcid.org/0000-0003-4740-0549
5 Universidade Federal de Santa Catarina Campus Florianópolis, Florianópolis, Santa Catarina, Brazil. E-mail: arcangelo.loss@ufsc.br Orcid: https://orcid.org/0000-0002-3005-6158
6 Universidade Federal do Triângulo Mineiro, Uberaba, Minas Gerais, Brazil. E-mail: iaraums@gmail.com Orcid: https://orcid.org/0000-0002-0880-7736
7 Universidade Federal do Triângulo Mineiro, Uberaba, Minas Gerais, Brazil. E-mail: soricina2@gmail.com Orcid: https://orcid.org/0000-0002-5953-2496
8 Instituto Federal do Triângulo Mineiro Campus Uberaba, Uberaba, Minas Gerais, Brazil. E-mail: jlrtorres@iftm.edu.br Orcid: https://orcid.org/0000-0003-4211-4340
Keywords: Conservation System, Soil Fauna, Vegetable.

MACROFAUNA EDÁFICA EM ÁREAS CULTIVADAS COM BRÁSSICAS IRRIGADAS EM SISTEMA DE PLANTIO DIRETO

RESUMO

Objetivo: Quantificar e qualificar a macrofauna edáfica presente nas áreas cultivadas com brássicas sob sistema de plantio direto de hortaliças (SPDH) em diferentes fases.

Método: O estudo foi conduzido em três diferentes áreas: 1-SPDH com um ano (SPDH1), 2-SPDH com três anos (SPDH3), 3-Mata Nativa (Em regeneração natural há 20 anos (MN20)); Nas profundidades: 0-10; 10-20 e 20-30 cm, com 5 repetições. Coletou-se a serapilheira de uma área de 0,50x0,50 cm e amostras de solo com um quadrado de ferro e 25x25x30 cm em cada parcela, onde foi quantificado número de indivíduos (ind m-2) e qualificado a riqueza total e os índices de diversidade e de equitabilidade da macrofauna.

Resultado e Conclusão: O manejo nas áreas SPDH1, SPDH3 e MN20 favoreceu o desenvolvimento da população dos grupos de Formicidae e Isoptera; A área SPDH3 na profundidade de 20 a 30 cm proporcionou as melhores condições para a maior frequência relativa do grupo Oligochaeta.

Implicações da Pesquisa: A avaliação da distribuição vertical favoreceu um conhecimento mais amplo da comunidade da macrofauna nos sistemas; O tempo de adoção do sistema de plantio direto de um ou três ciclos não afetou a densidade e diversidade da macrofauna.

Originalidade/valor: A maioria dos estudos com macrofauna edáfica tem sido realizada em áreas sob plantio convencional ou plantio direto de grãos ou em florestas, poucos estudos são realizados em áreas com hortaliças irrigadas, onde os processos que envolvem a matéria orgânica chegam a ser três vezes mais rápidos, onde a diversidade desta macrofauna é superior e precisa ser avaliada.

Palavras-chave: Sistema Conservacionista, Fauna do Solo, Hortaliças.

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1 INTRODUCTION

The organic matter deposited in the soil after each cycle in the no-till system (SPD) favors the establishment of soil invertebrate fauna, with a greater number of beneficial species, which will provide maintenance of the biological balance of the environment (Kamau et al., 2017). This equilibrium provides improvement in the physical, chemical and biological attributes of the soil, affecting the soil-plant interaction (Coelho et al., 2021).

This invertebrate fauna is directly affected by the intensity of land use, by the management system adopted or indirectly by the removal of the burlap (Lima et al., 2019; Kitamura et al., 2020). Studies by Machado et al. (2015) and Ferreira et al. (2019) have proven that the density, richness and diversity of this soil fauna are altered by farming activities, when compared to native forest fragments.

According to Lima et al. (2020), these parameters related to soil fauna can be used as bioindicators of soil quality, as it has high sensitivity to environmental or anthropic changes.

In the SPD, there is a greater number of groups of soil fauna, due to the greater quantity of organic waste injected into the soil (Ferreira et al., 2019), which also provides less variation in temperature and humidity (Torres et al., 2021). Lavelle et al. (2016) highlight that temperature and humidity are determinants in the population dynamics of soil fauna, as they
are parameters that affect the speed of decomposition of organic matter, favoring the increase in density of various groups of macro, meso and microfauna (Lima et al., 2019). When the SPD is performed in irrigated areas, the decomposition of the waste can be up to three times faster, when compared to those under natural climatic conditions (Silveira et al., 2021; Torres et al., 2019;), mainly due to the greater quantity and diversity of organisms present in the soil in these areas (Coelho et al., 2021).

In this context, the hypothesis tested in this study is that in irrigated areas there occurs a significant increase in population density and diversity of organisms present in the soil when compared to non-irrigated area. In this study, the objective was to quantify and qualify the soil macrofauna present in the areas cultivated with brassicas in direct planting system in different phases, in Uberaba, MG.

2 THEORETICAL FRAME

In little more than three decades, this Brazilian Cerrado has become the main area of production of meat and grain in the country, revealing itself as a new agricultural frontier for Brazil and the world, which is still in rapid expansion, being one of the important regions for maintaining the high level of Brazilian grain production in the country (Andrade et al., 2018), which reached 271.2 million tons in the 2021/2022 harvest, with an estimated new production record for 317.6 million hectares for the 2022/2 harvest (Conab, 2023).

However, intensive land use in the Cerrado areas for crop and animal production, monoculture and other inappropriate cultural practices, has caused loss of productivity, degradation of soil structure and natural resources in some states, negatively affecting plant development and predisposing the soil to different forms of water erosion (Torres et al., 2018).

Besides these listed problems, the transformations that have occurred in the Cerrado have also resulted in major environmental damage such as habitat fragmentation, extinction of biodiversity, invasion of exotic species, soil erosion, aquifer pollution, degradation of ecosystems, changes in burning regimes, imbalances in the carbon cycle and possibly regional climate changes (Klink and Machado, 2005).

Ecosystems with structurally more complex habitats such as forests tend to house more abundant and diverse soil fauna, due to the greater availability of ecological niches, shelter and food resources, associated with lower risk of predation, while homogeneous and simplified environments, such as monocultivates, tend to be more restrictive, favoring some groups of fauna over others (Spiller et al., 2018; Ferreira et al., 2019, Coelho et al., 2021).

Studies of soil management in the Cerrado have been conducted with the aim of developing strategies to reduce the impact of agricultural activities on this environment, and in this context, the direct planting system (SPD) has consolidated itself as a more sustainable production system for the region, which provides positive changes in the physical, chemical and biological attributes of the soils throughout the phases it goes through, however, only by reaching the maintenance phase can it express its full potential of benefits to the agroecosystem (Mazetto Junior et al., 2019; Torres et al., 2019; 2021).

The Cerrado region presents environmental peculiarities that make it distinct from the other agricultural environments of Brazil, because not always a technology recommended in other regions, can be used in this region, even if it is a common crop, therefore, the technical recommendations must be based on results of research developed in the local pedo-climatic conditions (Andrade et al., 2018), however the adoption of new technologies implanted aiming at increasing productivity, usually leads to an intensification of farming production systems, which can lead to different forms of soil degradation in the medium and long term, even associated with soil conservation techniques (Ralisch et 2008).
After being introduced into Brazil as a soil conservation system, to solve the erosion problems that plagued the state of Paraná, the SPD evolved technologically and transformed itself into an efficient production system, which expanded to the other Brazilian regions incorporating significant changes in agronomic practices, diminishing the periodic mobilization of the soil and promoting agrobiodiversity. Through crop rotation and different land uses, in addition to keeping the soil covered with growing crops or plant residues, which are associated with integrated management of pests, diseases and invasive plants, it meets the essential principles of sustainability of agriculture in the tropics and subtropics (Torres et al., 2018; Fuentes-Llanillo et al., 2021).

The SPD is among the most sustainable systems, in which, during sowing, the soil is not turned over and the mobilization occurs only in the planting line, keeping the remains of the previous crops on the surface, protecting the soil against the direct impact of the raindrops, with this, the system creates more favorable conditions for the growth of soil organisms, which are practically absent in the conventional planting system, due to the greater disaggregation of the soil, the increase of compaction and the lack of food, by the absence of cover (Lavelle et al., 2016).

High temperatures and inadequate soil management, such as conventional planting and the use of monoculture, can lead to a decrease in organic carbon stocks, as they affect the metabolic rates of microorganisms in the processes of decomposition of waste and soil organic matter, which does not occur in the SPD (Torres et al., 2019).

The effect of direct and conventional planting on the structure and function of the decomposers' food chain shows that the functioning of the chain is governed by means of the base resource that would be organic matter, so a change in this base resource promotes a cascading effect throughout the trophic chain. (Aquino et al., 2008). In the SPD, there is a greater diversity of edaphic arthropods than the conventional planting system, due to less mechanical disturbance in the soil and fewer variations in temperature and humidity (Baretta et al., 2006).

Soil macrofauna is one of the biological indicators that is directly related to various processes in the soil and have high sensitivity to environmental conditions, actively participating in the physical and chemical processes in the soil (Lima et al., 2020; 2021). Soil fauna can influence soil processes through two main pathways: directly, by the physical modification of the litter and soil environment, and indirectly, by interactions with the microbial community (Ferreira et al., 2019).

The diversity of soil fauna has been considered a key aspect for the maintenance of the structure and fertility of tropical soils (Brown et al., 2015), with an apparently faster response than other soil attributes, serving as biological indicators sensitive to changes in agroecosystems (Baretta et al., 2006).

The activity of these organisms, as well as their specificities, is fundamental for the sustainability of ecosystems, natural or managed, however, soil management practices (Araujo et al., 2018), fertilization, use of agrotoxics, monocultures, burning, among others, can strongly affect soil organisms, considerably modifying the abundance and diversity of the soil community, this modification occurs in different degrees of intensity, as a function of changes in habitat, food, creation of microenvironments and intra and interspecific competition (Alves et al., 2016).

Some studies have highlighted the effect of agricultural practices and soil management on soil invertebrate fauna, observed that depending on the type of system, the reactions of different groups of organisms can be negative, positive influencing the increase of pests or predators, depending on the type of environment provided, we can have direct effect on soil quality (Baretta et al., 2006; Brown et al., 2015; Lima et al. 2021).
Edaphic Macrofauna in Areas Cultivated with Irrigated Brassica Under No-Tillage System

These soil organisms, or soil macrofauna, are composed of invertebrate organisms that live some phases of their development in the soil or in the burlap, which can be classified according to the diameter of the body, being characterized as microfauna (diameter less 0.2 mm), which encompass protozoa, nematodes and rotifers. The mesofauna (diameter varies from 0.2 to 2.0 mm), represented by mites, collobuds, some groups of myriapods, some oligochaetes and crustaceans, while the macrofauna (diameter greater than 2.0 mm), are inserted termites (Isoptera), spiders (Araneae), snake louse (Diplopoda), centipede (Chilopoda), ants (Hymenoptera), earthworms (Oligochaeta) and molluscs (Mollusca) (Baretta et al., 2011; Marques et al., 2014).

Some organisms that comprise macrofauna are called "ecosystem engineers", such as Isoptera, Hymenoptera: Formicidae and Oligochaeta, because they directly or indirectly influence the availability of resources to other organisms by excavation and/or ingestion and transport of mineral and organic material from the soil, by the structures built as a result of these activities, including galleries, fecal acorns, mounds and nests, modifying the physical and chemical environment of the soil. The exclusion of macrofauna from the soil reduces decomposition and nutrient release from the mountain range (Lavelle et al., 2006; 2016).

Soil engineers are thus defined due to their contribution to the availability of resources and their spatial distribution in the soil, acting by physical means and biochemical processes in the creation of habitats, in the construction of biogenic structures and galleries, which can persist for a long period of time and which deeply affect the environment for smaller organisms (Amazonas et al., 2018).

3 METHOD

The study was developed in the experimental areas of the Federal Institute of the Triangle of Minas Gerais (IFTM), Campus Uberaba, MG, located between the coordinates 19°39'10.17" of South Latitude and 47°58'15.65" of West Longitude, with altitude ranging between 790 and 819 m, with the samples being carried out between the months of May and June of 2021 (winter), cas (SPDH) and native forest (MN) (Table 1).

Table 1. Description of areas of study

<table>
<thead>
<tr>
<th>Areas</th>
<th>Returns TRUE on success or FALSE on failure.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPDH1</td>
<td>An area in the initial stage of implantation of the direct planting system (SPD) of vegetables (SPDH), where the millet was cultivated until 90 days, when it was handled, being desiccated and grazed very close to the soil to bed, then the deer was done and the cabbage cuttings were transplanted to the place.</td>
</tr>
<tr>
<td>SPDH3</td>
<td>Area in SPDH there are 3 cycles, where millet is being used for straw production preceding the vegetable, which after handling, is done the devaluating and transplanting of seedlings, cabbage, green corn and corn simultaneously, then broccoli, in the 3 crop cycles, respectively.</td>
</tr>
<tr>
<td>MN20</td>
<td>Fragment of native forest for more than 20 years in a process of natural regeneration, reserved and without any anthropic activity, with a total area of 10.2 hectares.</td>
</tr>
</tbody>
</table>

SPDH1 = Area in direct planting system of vegetables (SPDH) in the first crop cycle; (SPDH); Area in SPDH3 in the third crop cycle; MN20 = Area of native forest in natural regeneration for 20 years.

The climate of the region is classified as Aw, hot tropical, according to updated Köppen classification (Beck et al., 2018), with rainy season in summer and dry in winter, presenting cold and dry winter, with annual average precipitation, temperature and relative air humidity of 1600 mm, 22.6 °C and 68%, respectively. During the first semester of 2021, a period with low rainfall was recorded in Uberaba, MG, according to data obtained at the IFTM meteorological station, Campus Uberaba, MG (Figure 1).
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The soils that predominate in the experimental areas (SPDH1 and SPDH3) were classified as dystrophic Red Latosol (Santos et al., 2018), with a sandy loam texture, which have the physical characteristics of 210, 720 and 70 g\(^{-1}\) of clay, sand and silt, respectively.

The area in SPDH1 shows in the arable layer from 0 to 0.20 m: 210 g kg\(^{-1}\) of clay, 710 g kg\(^{-1}\) of sand and 80 g kg\(^{-1}\) of silt, pH CaCl\(_2\) 5.1; 21.7 mg dm\(^{-3}\) of P (resin); 2.95 mmolcdm\(^{-3}\) of K\(^+\); 17,444 mmolcdm\(^{-3}\) of Ca\(^{2+}\) Mg\(^{2+}\) dm\(^{-3}\); H+Al 31 mmolcdm\(^{-3}\)e, MO 9.74 g dm\(^{-3}\) and 55 mmolcdm\(^{-3}\)e cationic exchange capacity (CTC), base saturation (V\%) of 44.

The area in SPDH3 has in the arable layer from 0 to 0.20 m: 210 g kg\(^{-1}\) clay, 720 g kg\(^{-1}\) sand and 70 g kg\(^{-1}\) silt, pH H\(_2\)O 5.9; 14.7 mg dm\(^{-3}\) P (Mehlich); 112, K+ mmolcdm\(^{-3}\) K\(^{+}\); 11, Ca\(^{2+}\); 4 mmolcdm\(^{-3}\) Mg \(^{2+}\); 17 mmolcdm\(^{-3}\) of H\(^+\)Al 10.34 g kg\(^{-1}\) of MO, 34.9 mmolcdm\(^{-3}\) of Cationic exchange capacity (CTC), base saturation (V\%) of 51.

The experimental design used was in casualized blocks (CBD), in a 3 x 3 factorial scheme, where areas with three different management systems were evaluated: 1 -SPDH1, 2 -SPDH3, 3 -MN20, in three depths: 0.0 - 0.10; 0.10 - 0.20 and 0.20 to 0.30 m, all with 5 repetitions.

The soil samples were collected using the methodology of soil monoliths proposed by the Tropical Soil Biological and Fertility (TSBF) program, described by Anderson and Ingram (1993) and adapted by Aquino et al. (2008), and collected in a sample area delimited by a metallic gage of 25 cm in length, 25 cm in width and 30 cm in height, at depths of 0 - 10, 10 - 20 and 20 - 30 cm (Figure 2), always in the period between 8 and 9 am. Initially, the leaf litter was collected and later the soil.

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**Figure 1**: Precipitation (mm) and average monthly temperature (°C) between November/2020 to June/2021, obtained at the IFTM Campus Uberaba Meteorological Station, while conducting the experiment.
Edaphic Macrofauna in Areas Cultivated with Irrigated Brassica Under No-Tillage System

Before the growing of the vegetables, in the three cycles mechanized seeding of the millet (*Pennisetum americanum* (L.) Leeke), with the fertilizer seeder mark Semina 2, with 5 lines spaced 0.20 m, with 50 seeds per meter, in experimental parcels of 30 m22 (6 x 5 m) of area, where they were cultivated approximately 100 days. It was then managed (desiccated) and then grazed close to the ground to bed, and then transplanted the seedlings under straw.

In the areas under study in SPDH, three cycles of vegetables were cultivated, before collecting for macrofauna evaluation, all following the recommendations of fertilization by Ribeiro et al. (1999).

In the first cycle (SPDH1) cabbage was grown and in the third cycle (SPDH3) broccoli in the area, in subdivided parcels, where doses of 150 kg ha\(^{-1}\) of N, 400 kg ha\(^{-1}\) of P\(_{2}O_{5}\) were applied and 240 kg ha\(^{-1}\) of K\(_{2}O\). The N and K were parcelled in the planting, 30 and 45 days after the seedlings were transplanted.

In the second cycle, sweet corn and green corn were grown in SPDH2, in subdivided parcels, where 32, 112 and 64 kg ha\(^{-1}\) of N, P\(_{2}O_{5}\) and K\(_{2}O\) were applied. For the toppings were applied 70 kg ha\(^{-1}\) of N and 70 kg ha\(^{-1}\) K\(_{2}O\) in the first topping at 20 days after sowing, in the second topping at 40 days after sowing 70 kg ha\(^{-1}\) of N was applied using as a source urea with 45% of N. The sowing fertilizer was mechanized and the covers were carried out with manual trolley.

In the areas in SPDH1 and SPDH3 the plants were irrigated whenever necessary, via conventional sprinkling, in order to raise to soil moisture always close to field capacity.

The litter and soil samples were separately packaged in identified and properly sealed plastic bags and subsequently taken to the soil laboratory of the IFTM. Afterwards the material was placed in trays, and afterwards manual collection of the individuals of the macrofauna was carried out with the help of tweezers. The individuals were packaged in bottles with 70% alcohol solution and subsequently identified.

After the macro-fauna had been sorted, the burlap was taken to the laboratory, placed in an oven with a forced circulation of air to dry at 65°C for 72 hours or until a constant mass, afterwards the quantified dry mass, expressed in kg ha\(^{-1}\).

All sorted organisms were taken to the Entomology Laboratory of IFTM Campus Uberaba for quantification and identification according to Pereira et al. (2018).
The density of the identified groups was expressed by individuals per square meter (ind.m\(^{-2}\)). For the total wealth was considered the total orders identified in the repetitions and the average wealth was calculated from the average of the total wealth. The Shannon Diversity Index (H) and, for fairness, the Pielou Index (J) have been calculated according to the following equations:

\[
\text{Shannon index (H)} = \sum pi \cdot Pi \log \text{ Equation (1)}
\]

Where:
\[
pi = ni/N, \text{ where: } ni = \text{Density of each group; } N = \text{Sum of the density of all groups.}
\]

\[
\text{Pielou index (J)} = H \cdot \log S^{-1} \text{ Equation (2)}
\]

Where:
\[
H = \text{Shannon index; } S = \text{Total number of groups present in the area (Total wealth).}
\]

The data were tested for normality and homocedasticity and because they did not meet the assumptions of ANOVA were submitted to the Kruskal-Wallis non-parametric test at 5\% significance, to compare the groups of macrofauna (R Core Team, 2019). In addition, the total percentage of individuals given from the litter and soil at depths 0.0 - 0.10, 0.10 - 0.20 and 0.20 - 0.30 m were calculated.

### 4 RESULTS AND DISCUSSION

The millet used as a roofing plant produced 8.1 Mg ha\(^{-1}\) of residues (dry mass) in SDPH1 and 8.5 Mg ha\(^{-1}\) of dry mass in SPDH3, which are values considered high, which are located in the range of 7 to 12 Mg ha\(^{-1}\). This is highlighted in studies conducted by Assis et al. (2017) and Pacheco et al. (2017) in other states and Torres et al. (2015; 207; 207 9; 2021), Mazetto Júnior et al. (2019) and Silveira et al. (2021) in the same region of the Minas Gerais Triangle, all in the Brazilian cerrado.

The total number of subjects quantified in the areas under SDPH1 was 1123 ind m\(^{-2}\), in the area of SPDH3 was 273 ind m\(^{-2}\) and 1533 ind m\(^{-2}\) the area of SPDH3 was \(^{2}\) and 1533 ind m-240. These individuals were distributed in 28 groups, of which eleven were distinguished, which are described in alphabetical order: Araneae, Coleoptera (larva) and Coleoptera (adult), Dermaptera, Diptera, Hemiptera: Auchenorryncha, Hemiptera of the suborder Heteroptera, Hymenoptera of the family Formicidae, Hymenoptera (Others), Isoptera, Oligochaeta, and, consequently the less frequent groups were grouped into "others" (Table 2).

<table>
<thead>
<tr>
<th>Groups</th>
<th>SPDH1</th>
<th>SPDH3</th>
<th>MN20</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ind m(^{-2})</td>
<td>ind m(^{-2})</td>
<td>ind m(^{-2})</td>
<td>ind m(^{-2})</td>
</tr>
<tr>
<td>Araneae</td>
<td>22 ± 4 a</td>
<td>13 ± 3 a</td>
<td>35 ± 8 a</td>
<td>70 ± 15</td>
</tr>
<tr>
<td>Coleoptera (larva)</td>
<td>80 ± 21 a</td>
<td>10 ± 6 b</td>
<td>54 ± 15 a</td>
<td>159± 42</td>
</tr>
<tr>
<td>Coleoptera (adult)</td>
<td>64 ± 27 b</td>
<td>16 ± 0 b</td>
<td>86 ± 21 a</td>
<td>166 ± 48</td>
</tr>
<tr>
<td>Dermaptera</td>
<td>45 ± 16 a</td>
<td>13 ± 6 ab</td>
<td>0 ± 0 b</td>
<td>58 ± 22</td>
</tr>
<tr>
<td>Diptera</td>
<td>16 ± 7 b</td>
<td>3 ± 3 b</td>
<td>19 ± 16 a</td>
<td>38 ± 26</td>
</tr>
<tr>
<td>Hemiptera: Auchenorryncha</td>
<td>16 ± 10 b</td>
<td>0 ± 0 b</td>
<td>29 ± 21 a</td>
<td>45 ± 31</td>
</tr>
<tr>
<td>Hemiptera: Heteroptera</td>
<td>493 ± 150 to</td>
<td>26 ± 13 b</td>
<td>0 ± 0 b</td>
<td>519 ± 163</td>
</tr>
</tbody>
</table>

Table 2. Density of individuals in the assessed soil profile (0.0 to 0.30 m), expressed in square meter (Ind m\(^{-2}\)), and ecological indices in the irrigated direct planting systems of vegetables and in the native forest, in Uberaba, MG.
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<table>
<thead>
<tr>
<th>Hymenoptera: Formicidae</th>
<th>186 ± 75 b</th>
<th>122 ± 30 b</th>
<th>531 ± 368 to</th>
<th>839 ± 473</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hymenoptera (others)</td>
<td>26 ± 22 a</td>
<td>10 ± 4 a</td>
<td>6 ± 4 a</td>
<td>42 ± 30</td>
</tr>
<tr>
<td>Isoptera</td>
<td>125 ± 117 b</td>
<td>0 ± 0 b</td>
<td>656 ± 282 to</td>
<td>781 ± 399</td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>29 ± 12 a</td>
<td>51 ± 25 a</td>
<td>58 ± 24 a</td>
<td>138 ± 61</td>
</tr>
<tr>
<td>Other *</td>
<td>21 ± 17 b</td>
<td>9 ± 7 b</td>
<td>58 ± 23 a</td>
<td>88 ± 47</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1123 ± 478</td>
<td>273 ± 97</td>
<td>1532 ± 782</td>
<td>2928 ± 1357</td>
</tr>
</tbody>
</table>

**Total Wealth**: 16

**Shannon**: 2.74, 2.69, 2.16

**Pielou**: 0.68, 0.73, 0.58

Values followed by the same lower case letters in the row do not differ from each other by the 5% Kruskal Wallis test. SPDH1 = System of direct planting of vegetables implanted 1 year ago; SPDH3 = System of direct planting of vegetables implanted 3 years ago; MN20 = Native forest in regeneration 20 years ago. * = Other: Acari, Blattodea, Chilopoda, Diplopoda, Diptera, Enchytraeidae, Entomobryomorpha, Isopoda, Diptera (larva), Hymenoptera: Formicidae(larva), Lepidoptera (larva), Opilionida, Orthoptera, Psocoptera, Mantodea and Symphyla.

Among the 11 groups, Hymenoptera: Formicidae, Isoptera and Hemiptera: Heteroptera stood out in terms of density, with over 490 ind m⁻², with the Hemiptera: Heteroptera group having its highest density in SPDH1, while for Formicidae and Isoptera the same occurred for the area in MN20.

The Formicidae family stood out in the three areas evaluated, presenting the total population of 839 ind m⁻², having significantly higher values in the area of MN20 (531 ind m⁻²), similar results to those observed by Martins et al. (2017), probably due to the adaptability of the group to the different changes in the environment and its detrimental characteristic, acting on the fragmentation of the serapilheira existing in the areas of native forest and as predators of other organisms (Menezes et al., 200009). According to Souza et al. (2015) and Ferreira et al. (2019), the organisms of the Hymenoptera: Formicidae group deserve prominence due to their importance in the fragmentation, movement and transformation of soil organic materials, facilitating and making food available to other smaller organisms.

This Hymenoptera: Formicidae group is the dominant group in most terrestrial ecosystems, in number of individuals, biomass and ecological functions, which has a wide geographical distribution, which can be sampled and identified easily and are sensitive to changes in the environment (Korasaki et al., 2013). Oliveira et al. (2014) highlight the importance of ants in studies related to biodiversity assessment, ecosystem conservation and the relationship with other invertebrates for the enhancement of soil quality, as they grind vegetation into smaller particles, then move them vertically and horizontal, forming aggregates and increasing the porosity of aeration and drainage, which by fragmenting and mixing the organic material with the soil, contributes to the cycling of nutrients.

The Isoptera group had its largest population in the M20, quantified at 656 ind m⁻², with 125 ind m⁻² in SPDH1 and zero in SPDH3. This behavior can be justified because MN20 presents the greatest heterogeneity in relation to vegetation, which implies having a more diverse range of litter, a larger root system, soils with high aluminum levels and low pH values, due to the high buffer power of organic matter (Eberling et al., 2008), which favors the occurrence of termites or termites in the area.

According to Brown et al. (2015), termites are social insects and fundamental in the process of decomposition and nutrient cycling, which contribute to supporting and regulating ecosystem services, and their presence in the MN20 has a direct relationship with the layer of litter that exists in the place, which accumulates over the years and can serve as a food substrate for their development.

In a similar study, Santos et al. (2017), Araújo et al. (2018) and Ferreira et al. (2019), also observed high density of Isoptera in their reference areas, when compared to the other areas under study, justifying that they are places where greater availability of food occurs for these...
invertebrates, in addition, are responsible for the construction of an extensive network of nests and tunnels in the soil, depending on their needs for food search, protection and environmental control.

In SPDH1, there was a high density of the Hemiptera: Heteroptera (493 ind m\(^{-2}\)) group, when compared to the other areas evaluated, which is possibly related to the history of use of the area, which was explored over a long time with pastures, then by two successive cultivations of corn, one year fallow, only after was introduced the SPD. When implanting the system, they opted for millet for the initial production of straw in the area.

Millet (*Pennisetum glaucum* (L.) R. Brown.) is one of the most widely used crops in the Brazilian cerrado for producing straw in quantity, which due to its high carbon/nitrogen (C/N) ratio, its residues persist longer on the soil surface protecting it against erosive processes, in addition to cycling high amount of nutrients (Torres et al., 2019, 2021; Silveira et al., 2021). Rodrigues et al. (2016) highlight that the use of grasses for straw production favors the emergence of a greater number of organisms in the surface layers, due to the greater amount of dry mass produced and in different stages of decomposition.

Within the Hemiptera: Heteroptera group, the insect-pest known as the grazing brownish bedbug (*Scaptocoris carvalhoi* Becker) was the one found in greatest quantity. According to Oliveira and Malaguido (2004), this bedbug commonly occurs in places cultivated with various crops, mainly in places where soybeans are cultivated or pastures.

When analyzing the calculated indices of the three areas from population density in insects, it was observed that the area in SPDH1 presented greater total wealth and Shannon index (H), when compared to SPDH3 and MN20, while the area in SPDH3 presented higher Pielou index (J). The high Shannon index (H) and Pielou index (J) in SPDH3 are associated with low density of individuals, indicating that the area presents a uniform distribution of the groups of organisms present. In contrast, the MN20 presents the lowest indices with high population density, indicating that the distribution of the groups is uneven, since the Isoptera group represents 42.8% of the organisms sampled in this area.

When analyzing the total wealth, Shannon (H) and Pielou (J) indices by treatments and depths, it was observed that the total wealth values for the MN20 in the leaf litter and in the depths were higher than those observed in the other areas evaluated, however, the H index (diversity) was higher in the leaf litter and at 10 cm in depth, where there is a higher content of organic matter and decreased in depth, while the J index (fairness) was lower in the more superficial layers to MN20 and the SPDH3 shows greater uniformity in the leaf litter and layers from 10 to 20 and 20 to 30 cm (Table 3).

<table>
<thead>
<tr>
<th>System</th>
<th>Ind m(^{-2})</th>
<th>Total Wealth</th>
<th>Shannon</th>
<th>Pielou</th>
</tr>
</thead>
<tbody>
<tr>
<td>Billiard</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPDH1</td>
<td>204,80</td>
<td>11.00</td>
<td>2.97</td>
<td>0.86</td>
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<tr>
<td>SPDH3</td>
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<td>0.91</td>
</tr>
<tr>
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<td>2179,20</td>
<td>18.00</td>
<td>2.59</td>
<td>0.62</td>
</tr>
<tr>
<td>0 to 10 cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPDH1</td>
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<td>11.00</td>
<td>2.35</td>
<td>0.68</td>
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<tr>
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<td>0.63</td>
</tr>
<tr>
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<td>18.00</td>
<td>2.22</td>
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<td>10 to 20 cm</td>
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<td></td>
</tr>
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<tr>
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<tr>
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<td>1.32</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Table 3. Density of soil macrofauna (Ind m\(^{-2}\)) and ecological indices in the mountain range and the different soil layers of the different management systems, in Uberaba, MG.
The MN20 has the highest total wealth index, which is related to the greater diversity and heterogeneity of plants and plant residues deposited on the soil, as also observed by Martinset al. (2017). Despite the high density of individuals and the total wealth of the MN20, there is greater uniformity found in SPDH3, which is the group of lowest wealth, which is justified by the lower density of individuals per square meter (Ind m⁻²) in this area.

In the SPDH3, the density of individuals and the total wealth values were relatively low when compared with the MN20 and SPDH1, however, the H and J indices were high in relation to the other investigated areas, which may indicate stability in relation to the groups of organisms. Crepaldi et al. (2014), Ferreira et al. (2019) and Kitamura et al. (2020) highlight that as the soil organic matter content increases, diversity values also increase, due to the increased availability of plant residues from cultivated plants and crop rotation.

The analysis of the relative frequency (RF) in the serapilheira (SP) shows that there was a higher occurrence of the Diptera groups in the MN20 (40%), Formicidae in the SPDH3 (35.3%) and Coleoptera groups in the SPDH1 (23.4%) (Figure 3). These predominant groups in the mountain range are responsible for the fragmentation of plant residues (Fomicidae and Isoptera) and predators, phytophagi and saprophagi (Diptera).

**Figure 3:** Relative frequency of the groups of macrofauna organisms, in the different management systems, in the mountain range and at depths 0-10, 10-20 and 20-30 cm, in Uberaba, MG

In their study of areas with natural climatic conditions in the same region, Coelho et al. (2021) also observed high frequency of Diptera in the MN20, where they highlighted the importance of the group as insects acting on the decomposition of organic matter. Anderson (2015) points out that these insects are phytophagous, decomposing, pollinating and predating insects, which in addition to their importance in the decomposition of organic matter, still act in the biological control of other pests. According to Souto et al. (2008) and Lima et al. (2019), the Dipterases and the other groups that occur on a larger scale, collaborate directly or indirectly for the sustainable
functioning of terrestrial ecosystems, being indispensable in the internal regulation of the energy flow of the studied agro-ecosystems and of the biome itself.

The Formicidae group was observed with the high percentage of relative frequency in the serapilloin in the three areas under study, 21.9% in SPDH1, 35.1% in SPDH3 and 26.7% in MN20, which can be justified by the high quantity of vegetable residues of the millet after being handled, which increases the availability of food and nesting sites, consequently greater will be the need for the presence of this group in the place, to fragment this material deposited on the soil surface (Santos et al., 2006).

The presence of the Coleoptera group in the areas under study can be attributed to the diversity and rusticity of these species, which have different eating habits, as they are insects responsible for nutrient cycling, bioturbation, plant growth, parasite control, and even pollination and trophic regulation (Souto et al., 2008). They are considered good environmental indicators, because they have high diversity, occupy different trophic levels and have specific characteristics within their ecological niches, because they can be phytophagous, saprophagous and predatory, providing greater sensitivity to environmental changes due to the management used (Spiller et al., 2018; Kitamura et al., 2020).

It was observed that the Isoptera group showed higher relative frequency in the 3 depths evaluated in the MN20, with 63.3% in the 0-10 cm layer, 26.5% in the 10-20 cm layer and 46.9% in the 20-30 cm layer. The group of Formicidae organisms stood out in the 0-10 cm layer in SPDH3 (62.7%).

When analyzing the Hemiptera: Heteroptera group, a high density of the species Scaptocoris sp., popularly known as the brown root bug, was noted, and more nymphs than adults were found in soil samples. This bedbug has a wide geographical distribution in the Neotropical Region, and in Brazil there are records of occurrence of this group of insects from North to South, causing economic damage in crops and pastures, which are more frequent in regions of Cerrado (Oliveira et al., 2004).

Studies show that the population density analysis of Scaptocoris sp. indicate that during the period from April to August, when rainfall decreases, the population of nymphs tends to be larger than that of adults, however, the areas of SPDH1 and SPDH3 are irrigated, and collections were carried out during the dry period of the year, which may justify the presence of high density of nymphs of Scaptocoris spp. (Nardie et al., 2007).

The high relative frequency of the Oligochaeta group (earthworms) in the 20-30 cm SPDH3 may be related to the accumulation of organic material on the surface, which indicates that the evaluated soils are undergoing transformation, in a process of dynamic restructuring, as these organisms promote the modification of physical attributes by making resources available to other individuals or transporting soil particles for the formation of nests and galleries, resistant organomineral structures (Abreu et al., 2014).

The population fluctuations of the Oligochaeta group in crop areas depend on the management systems adopted, the non-mobilization of the soil and the increase of organic matter over time, which provide a better environment for the activity and establishment of earthworms, since they are organisms that create biogenic structures (galleries and coprolites), which alter the physical and chemical attributes of the soils where they live (Souza et al., 2015; Lima et al., 2020).

Analyzing the vertical distribution of individuals from the taxonomic groups of the macrofauna observed in the different types of soil management, one can show the similarity existing between the areas in SPDH1 and SPDH3, with the predominance of greater number of individuals in the surface layer (0-10 cm). The same did not occur in the MN20, since the highest percentage of individuals occurred in the burlap, indicating that the continuous intake of organic matter in this environment favors the feeding of organisms (Figure 4).
Edaphic Macrofauna in Areas Cultivated with Irrigated Brassica Under No-Tillage System

Figure 4: Vertical distribution of individuals of the macrofauna in the mountain range at different soil depths, in the direct planting systems of irrigated vegetables (SPDH1 and SPDH3) and native forest in regeneration for 20 years (MN20).

The similarity in percentage between SPDH1 and SPH3 can be related to the time of adoption of the system, as they are still in the initial phase of implantation, as highlighted by Mazetto Junior et al. (2019). The layers of 10-20 cm and 20-30 cm showed a low percentage of individuals in the vertical distribution, this can be attributed to the fact that the areas are irrigated, since the humidity favors the presence of macrofauna in the surface layers. According to Coelho et al. (2021) humidity is a limiting factor of macrofauna, with this the rainy period may favor a higher density of organisms in the mountain range and also in the surface layer of the soil, Lima et al. (2021) also verified this relationship.

According to Ferreira et al. (2019) Lima et al. (2019, 2020), the time of adoption of the system exerts strong influence on the macrofauna community, because the longer the time under no-till system (SPD), the greater the diversity of organisms, however this was not observed in this study. Coelho et al. (2021) evaluated areas in SPD in more advanced stages, in the transition phase (6 years) and consolidation phase (17 years), and observed that in the SPD, with regard to macrofauna, the areas tend to be with their indices closest to the native forest when they reach the end of the consolidation phase of the system, proving to be a production system with greater sustainability.

5 CONCLUSION

Management in the areas SPDH1, SPDH3 and MN20 favored the development of the population of the Formicidae and Isoptera groups;

The SPDH3 area at a depth of 20 to 30 cm provided the best conditions for the relative higher frequency of the Oligochaeta group;

The assessment of the vertical distribution favored a broader knowledge of the macrofauna community in the systems;

The adoption time of the one- or three-cycle no-till system did not affect the density and diversity of soil macrofauna.
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