EFFECT OF ORGANIC AND BIODYNAMIC MANAGEMENT ON CHEMICAL CHARACTERISTICS, MACROFAUNA AND BIOLOGICAL ACTIVITY OF SOIL IN A VINEYARD OF CV. BRS CARMEN

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ABSTRACT – Organic agriculture is based in the improvement of biodiversity and maintenance of plant cover, that could favor nutrient cycling, soil aggregation, water storage, organic matter maintenance, macro and microorganisms. In this study, we compared the characteristics of the soil in areas with grapevines cv. BRS Carmem cultivated under organic and biodynamic management. The trial was carried out in Guarapuava, Paraná State, Southern Brazil from September 2013, when the grapevines were planted, until June 2017. The soil was handled in the same way in both treatments, but in the plots of biodynamic treatment the following biodynamic preparations were applied: manure horn (500), *Equisetun* (508) and Fladen. All plants were fertilized with the same organic compost, however, those from the biodynamic treatment received the preparations 502 (*Achillea millefolium*), 503 (*Chamomilla officinalis*), 504 (*Urtica dioica*), 505 (*Quercus robus*), 506 (*Taraxacum officinale*) And 507 (*Valeriana officinalis*). The following soil traits were evaluated: chemical analysis (0-10 and 10-20 cm), quantification of macrofauna of the soil with pittfall trap and soil monoliths, number of cysts of ground-pearls (*Eurhizococcus brasiliensis*) in the vine roots and ß-glucosidase enzyme activity in soil. Soil with biodynamic preparations showed higher K and H + AL content in both vertical sections. It was possible to observe a larger number of ground-pearl cysts in the roots of plants under organic treatment. No statistical difference was observed for ß-glucosidase enzyme activity.

Keywords: agroecology, β-glucosidase, *Eurhizococcus brasiliesis*, *Vitis* spp.

INTRODUCTION

The number of organic farmers in Brazil increased 300% from 2010 to 2018, reaching 22,000 farms in 2019 (MAPA, 2019). The total area of organic production in Brazil reaches 1.1 million hectares, mainly in the Northeast, South and Southeast (MAPA, 2019). In these areas, the organic practices can follow different lines of production, such as biodynamic system. Organic agriculture values biodiversity and maintenance of plant cover, which favors nutrient cycling, soil aggregation, water storage and organic matter maintenance. In turn, biodynamic management is based in the uses of specific fermented preparations proposed by Steiner (1861–1925). They are made from medicinal plants, manure and silicon (quartz), which are wrapped in animal organs, buried in the soil and subjected to Earth influences and their annual rhythms (STEINER, 2010).

These procedures are believed to stimulate the soil nutrient cycle, improve plants photosynthesis, optimize the evolution of organic compost improving soil quality and crop yield (KOEPF et al, 1983). Thus, the soil fauna is also benefited by the increase in the quality, quantity of food and shelter for these organisms that live in the environments near the ground (BARETTA et al., 2003; TOMICH et al., 2011).

Many biodynamic preparations are applied in the soil, and its effects have been studied in order to investigate the variations in soil microbial, arthropod and earthworm communities, in comparison to conventional or other organic managements (BURNS et al., 2016; FAUST et al., 2017). Reganold and Palmer (1995) analyzed soils in farms of New Zealand under conventional and biodynamic management and they demonstrated that soils from biodynamic management showed higher biological,

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physical and chemical quality than soils from conventional system. Carpenter-Boggs et al. (2000a), in a study of the biological characteristics of the soil, showed that those managed in organic and biodynamic systems had the same microbiological status, however, both were more biologically active than the soil that did not receive organic fertilization. In addition, they increased soil microbial biomass, soil basal respiration rate, dehydrogenase activity, mineralized carbon, and earthworm (*Lumbricus terrestris*) population and biomass. Flieβbach et al. (2007) studied crop rotations in a biodynamic, organic and conventional system for a long period, and evaluated the chemical and biological quality in the soil. According to their results the organic carbon content was maintained throughout the experiment in biodynamic treatment and decreased in all others. Soil pH was maintained in biodynamic and organic treatments and had a slight decrease in conventional treatments. The biological quality indicators made in the last cycle of the crops indicate greater activity of the enzyme dehydrogenase in the biodynamic treatment when compared to the others, and there was no difference for basal respiration. The metabolic coefficient of CO_2 was higher in conventional treatments when compared to biodynamic, which indicates a higher microbial requirement in conventional systems and greater CO_2 release. There was no difference between the biodynamic and organic treatment for this parameter.

In vineyard, the biodynamic management systems have been studied in order to offer an environmentally sustainable approach to wine production. Such studies demonstrated that the modifications in the plant and the soil promoted by biodynamic management could improve the chemical characteristic of the wine due to changes in berry composition (MARTIN, RASMUSSEN, 2011; MULERO et al., 2011; PARPINELLO et al., 2019; PIVA et al., 2019). Nevertheless, little is known about the effects of biodynamic management of vineyards on soil chemical and biological characteristics in a medium and a long term.

In this study, we aimed to evaluate the effect of the use of the biodynamic preparations in the soil characteristics of a vineyard cv. BRS Carmem.

MATERIALS AND METHODS

The trial was carried out in Guarapuava, Paraná State, Brazil (25° 41'S 51° 38'W, 1,100 m a.s.l.). The climate according to the classification of Köppen is Cfb (subtropical mesothermic moist), temperate, without dry season defined, with warm summer and moderate winter (WREGE et al., 2011).

The plantlets of grapevines cv. Carmem grafted on 'Paulsen 1103' rootstock were planted on September 21, 2013, spaced 3 meters between rows and 1.5 meters between plants, corresponding to a density of 2,222 plants ha^{-1}. The experimental design was in randomized blocks, with two treatments and six replicates and experimental plot consisting of seven plants. The treatments were as follows:

T1) Organic: based on organic production standards (IN 46/2011, MAPA, 2011); but without the prepared biodynamic solutions.

T2) Biodynamic: based on the precepts of biodynamic agriculture including the use of preparations (JOVCHELEVICH & VIDAL, 2016).

The biodynamic preparations (Table 1) were divided into two groups: a) applied by spraying in the soil: 500 (Horn-manure); 508 (*Equisetum hyemale* L.) and Fladen; b) applied to the organic compost: 502 (*Achillea millefolium* L.), 503 (*Chamomilla officinalis* L.), 504 (*Urtica dioic* L.), 505 (*Quercus robus* L.), 506 (*Taraxacum officinale* Web), for each preparation 2 g 25 m^{-3}, and 507 (*Valeriana officinalis* L.) (2 mL 25 m^{-3}).

Table 1 - Date of applications of biodynamic preparations in each year in soil (Guarapuava-PR)

Biodynamic preparations	Dose	2013	2014	2015	2016
Fladen	100 g 30 L^{-1} ha^{-1}	11/22	03/13 06/24	01/21 05/04 09/24	09/21
Manure horn (500)	100 g 70 L^{-1} ha^{-1}	11/02 12/13	01/21 10/21 11/05 and 25	05/04 07/30 09/24	09/21
Equisetum (508)	5% (150 ml 3 L^{-1})	--	11/01 and 30 12/11	01/20 11/28	--

During the vegetative period of the plants (September/February - Spring/Summer), in the first year (2013/14) average maximum temperatures were 25.4 °C, average temperatures of 20.1 °C and minimum temperatures of 14.8 °C. The mean relative humidity and the total precipitation of 69.9% and 934.8 mm respectively. In the second year (2014/15) the average maximum temperatures were 25.9 ºC, average temperatures of 20.8 ºC and minimum of 15.8 ºC. The mean relative humidity was 72.7% and the total precipitation was 1391.9 mm. In the third year (2015/16) the average maximum temperatures were 25.5 °C, average temperatures of 21.0 °C and minimum temperatures of 16.4 °C. The mean relative humidity was 76.8% and the total precipitation was 1227.7 mm.

Table 2 - Climatic data during the vegetative period of the plants (Spring/Summer) 2013/14, 2014/15 and 2015/16 (Guarapuava, PR)

Climatic data	2013/14	2014/15	2015/16
Average maximum temperature (º C)	25.4	25.9	25.5
Average temperature (º C)	20.1	20.8	21.0
Average minimum temperature (ºC)	14.8	15.8	16.4
Mean relative humidity (%)	69.9	72.7	76.8
Total precipitation (mm)	934.8	1391.9	1227.7

Chemical analysis of soil: Samples were collected in June 2014, with three collections per experimental plot totaling 12 samples (two treatments and six replications). Samples were taken at depths of 0-10 and 10-20 cm. The following chemical traits were analysed: pH (extraction with $CaCl_2$ solution 0.01 mol L^{-1}), organic matter content (Wet Oxidation), contents of P (Mehlich-I), K (Mehlich-I), Ca, Mg (KCl mol L^{-1}) and H + Al (SMP solution), saturation bases (SB), exchange capacity cations (CTC), V%, S, B, Fe, Cu, Mn and Zn (PAVAN et al., 1992).

Macrofauna of the soil: the samples were taken in September 2014 and 2015 with cylindrical plastic containers pitt-fall traps (8 cm in diameter), placed down to the depth in the soil. These traps were filled with 200 mL of 5% detergent water solution and kept in the soil for fourteen days. Samples were collected manually, using tweezers to separate soil and plant fragments. The identification of the organisms was performed at the class, order and family level using a stereomicroscope (Nikon, SMZ 745T, Japan), with 40-fold zoom (LOPES et al., 1994).

Soil monoliths with dimensions of 25x25x25 cm were excavated with a straight shovel, according to the standard protocol of the Tropical Soil Biology and Fertility Program (TSBF) (ANDERSON & INGRAM, 1993). These samples were taken on the row and between the rows of each experimental plot and stored in plastic bags. In the laboratory, the samples were placed in plastic trays, where the organisms were separated and stored in bottles containing 70% alcohol for later counting and identification. All invertebrates larger than 2.0 mm (Macrofauna) in length were recorded. Relative frequency of major taxonomic groups, density, Shanon-Wiener diversity index and Simpson dominance were analyzed by the DIVES program (DIVES, 2015; SIMPSON, 1949; SHANNON, 1948). For normalization of the data the transformation was done (Root (x + 1)).

Number of Eurhizococcus brasiliensis cysts: At the end of the third cycle (01/08/2016), five plants were removed per treatment to count the number of pearl cysts in the grapevines roots. An area 40 cm wide by 40 cm long and 40 cm deep (0.064 m^3) was excavated around the plant and counted the number of pearl cysts in the roots of the plants and in the soil.

Soil biological activity (ß-glucosidase): soil samples were collected in the plant row in September 2014 and 2015. With the use of a cutter, three samples per experimental plot in the 0-15 cm depth were taken, homogenized and conditioned in plastic bags for later storage in a frezer at -20 ºC. Three days before the analyzes were carried out the samples were reassembled in a refrigerator at 4 °C. A 50 g portion of soil was removed from each sample for determination of moisture content by oven drying at 65 °C to constant weight.

The activity of the β-glucosidase enzyme was determined according to procedures described by Dick et al. (1996). The substrate used in the reaction of this enzyme was 0.025M p-nitrophenyl-β-D-glucopyranoside (0.025M PNG). Samples of 1.0 g were placed in 30 mL falkon tubes, using a control where only the substrate was added after incubation. Then, 250 µL of Toluene, 4.0 mL of Mcllvaine pH 6 solution were added to all samples and 1.0 mL of 0.05M PNG were added except controls. The tubes were incubated at 37 °C for one hour. After incubation, 1.0 mL of 0.5M $CaCl_2$, 4.0 mL of Tris-Hydroxymethyl-Amino-Methane (THAM pH 12) and 1.0 mL of 0.05M PNG (control only) were added. The samples were then filtered on paper No. 2. The intensity of the yellow coloration of the filtrate was determined in a spectrophotometer at 410 nm.

The amount of p-nitrophenol formed in each sample was determined based on a standard curve prepared with known concentrations of p-nitrophenol (0, 10, 20, 30, 40, 50 mg of p-nitrophenol mL^{-1}). The enzyme activity was expressed in µg of p-nitrophenol released per hour per gram of soil (µg p-nitrophenol $h^{-1}g^{-1}$ dry soil).

All data was submitted to analysis of variance and the means were compared by the T - LSD test at 5% probability, using the SISVAR version 5.3 program. (FERREIRA, 2014).

RESULTS

For the results of soil chemical characteristics, in June 2014, one year after planting, biodynamic plots showed higher content of H + Al (16 %), K (39 %) and Cu (22 %) in depth 0-10 cm in comparison to the organic. Nevertheless, no statistical differences were observed for pH, OM, P, Ca, Mg, SB, CTC, V%, S, B, Fe, Mn and Zn. At depth 10-20 cm, there was higher H + Al (20 %) and K (52 %) content for the biodynamic treatment and higher V% (7 %), for the organic treatment. For the other characteristics, there was no statistical difference (Table 3).

Table 3 - Chemical characteristics of soil in vineyard of cv. BRS Carmem at depths 0-10 and 10-20 (Guarapuava-PR, 2014)

Item	Organic	Biodynamic	Organic	Biodynamic
	0-10	0-10	10-20	10-20
pH $CaCl_2$	5.90	5.72 n.s.	5.77	5.66 n.s.
Mo g/dm^3	49.25	49.32 n.s.	47.27	45.95 n.s.
P mg/dm^3	18.50	13.40 n.s.	6.05	4.20 n.s.
H+Al $cmol_c/dm^3$	2.86	3.41**	2.86	3.61**
K $cmol_c/dm^3$	0.54	0.83**	0.30	0.63**
Ca $cmol_c/dm^3$	6.75	5.75 n.s.	5.42	4.77 n.s.
Mg $cmol_c/dm^3$	2.30	3.10 n.s.	2.47	2.70 n.s.
SB $cmol_c/dm^3$	9.56	9.68 n.s.	8.18	8.07 n.s.
CTC $cmol_c/dm^3$	12.42	13.10 n.s.	11.04	11.69 n.s.
V%	76.77	73.70 n.s.	74.05**	69.02
S	13.67	13.15 n.s.	9.87	13.22 n.s.
B	0.34	0.34 n.s.	0.37	0.31 n.s.
Fe	18.12	18.05 n.s.	19.02	18.02 n.s.
Cu	1.17	1.50**	1.12	1.40 n.s.
Mn	20.05	23.02 n.s.	15.85	15.00 n.s.
Zn	1.22	2.47 n.s.	1.67	0.97 n.s.

** significant T-LSD test (P <0.05),n.s. not significant.

The evaluation of insect macrofauna was performed by two cycles (2014/15 and 2015/16), in two ways, collecting insects in the soil in the row, between the rows and using pitfall trap on the surface. Shanon-Wiener diversity and Simpson dominance were evaluated. There was no statistical difference during the two cycles evaluated (T test – LSD, p>0,05%), (Figure1).

For soil monolith collection, 10 taxonomic groups of macroinvertebrates were identified, with higher frequency for Haplotaxida, Coleoptera, Formicidae and Blattodea. In 2014/15 cycle, 233 macroinvertebrates were collected in planting row, with the following frequency: Haplotaxida (26%), Coleoptera (12%), Formicidae (33%) and Blattodea (21%). The largest variation was observed for biodynamic treatment (20.6%) compared to organic (0.4%). For the samples collected between rows, 167 individuals were collected, including Haplotaxida (16%), Coleoptera (19%) and Formicidae (48%) (Table 4).

In 2015/16 cycle, 726 individuals were collected in planting row, classified as Haplotaxida (13%), Formicidae (51%) with variation of 16% for biodynamic and 35% for organic treatment, Blatodea (23%) with 22%

for treatment biodynamic and 1% for organic. Between rows, 328 individuals were collected: Haplotaxida (33%), Formicidae (22%), Blatodea (23%) and Hemiptera (12%) (Table 5). No significant differences were observed between organic and biodynamic management systems for the factors analyzed.

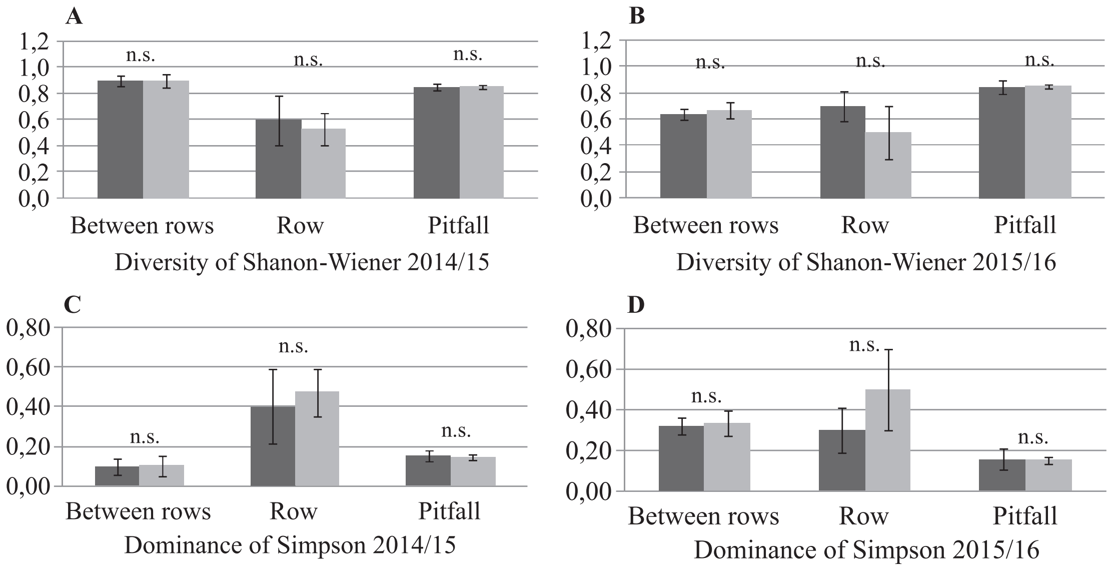

Figure 1 - Diversity of Shanon-Wiener 2014/15 (A) 2015/16 (B), and Dominance of Simpson 2014/15 (C) 2015/16 (D). Collection of samples on the row, between the rows and in the Pitfall trap, Guarapuava-PR, 2016. n.s. no significant.

Table 4 - Relative frequency (standard deviation) of major taxonomic groups identified with soil collection (25x25x25 cm) in planting row and between rows in 2014/15 (Guarapuava-PR, 2017)

	planting row 2014/15			between rows 2014/15		
	Organic	Biodynmic	Total	Organic	Biodynâmic	Total
Haplotaxida	3.83 (2.48)	6.50 (6.09)	62	2.30 (2.25)	2.33 (2.73)	28
Coleoptera	2.16 (1.72)	2.83 (1.47)	30	2.50 (1.37)	3.00 (1.78)	33
Formicidae	6.00 (6.03)	7.16 (4.02)	79	5.16 (4.66)	8.16 (7.93)	80
Chilopoda	0.16 (0.40)	0.33 (0.51)	3	0.33 (0.51)	0.33 (0.51)	4
Gryllidae	0.16 (0.40)	0.5 (0.54)	4	0.00 (0.00)	0.00 (0.00)	0
Blattodea	0.16 (0.40)	8 (12.94)	49	1.16 (0.98)	1.16 (1.47)	14
Hemiptera	0.00 (0.00)	0.00 (0.00)	0	0.16 (0.40)	0.16 (0.40)	2
Mollusca	0.00 (0.00)	0.00 (0.00)	0	0.00 (0.00)	0.00 (0.00)	0
Isopoda	0.00 (0.00)	0.00 (0.00)	0	0.33 (0.81)	0.00 (0.00)	2
Arachnida	1.16 (0.40)	0.83 (0.98)	6	0.66 (0.81)	0.00 (0.00)	4
Density	12.60 (6.65)	26.16 (15.10)	233	12.66 (5.81)	15.10 (10.94)	167

Table 5 - Relative frequency (Standard deviation) of major taxonomic groups identified with soil collection (25x25x25 cm) in planting row and between rows in 2015/16 (Guarapuava-PR, 2017)

	Macrofauna Row 2015/16			Macrofauna Between Row 2015/16		
	Organic	Biodynamic	Total	Organic	Biodynamic	Total
Haplotaxida	6.00 (2.25)	10.16 (7.75)	100	7.5 (4.13)	10,5 (3.39)	108
Coleoptera	3.66 (1.75)	5.16 (1.60)	53	1.33 (1.03)	1.33 (0.81)	16
Formicidae	42,5 (42.5)	19.33 (7.52)	371	6.16 (5.15)	6.16 (3.31)	74
Chilopoda	0,16 (0.40)	1.00 (0.89)	7	0.5 (0.83)	0.16 (0.40)	4
Gryllidae	0.50 (0.83)	0.50 (0.54)	6	0.33 (0.51)	0.50 (0.54)	5
Blattodea	2.00 (4.89)	26.6 (35.6)	172	7.00 (7.27)	6.00 (7.58)	78
Hemiptera	0.83 (1.16)	0.83 (1.60)	10	0.83 (1.16)	5.83 (8.30)	40
Mollusca	0.00 (0.00)	0,33 (0.51)	2	0.00 (0.00)	0.00 (0.00)	0
Isopoda	0.00 (0.00)	0.00 (0.00)	0	0.00 (0.00)	0.00 (0.00)	0
Arachnida	0.00 (0.00)	0.83 (0.75)	5	0.33 (0.51)	0.16 (0.40)	3
Density	56.10 (42.40)	64.80 (32.20)	726	24.00 (11.30)	30.60 (13.72)	328

Eurhizococcus brasiliensis. The number of ground-pearl cysts (*Eurhizococcus brasiliensis*) in grapevines rhizosphere was performed in two sampling (08/01/2016 and 01/19/2017). In the first evaluation, grapevines under organic treatment showed values 35% higher than the plants treated with biodynamic preparations (T test – LSD, p≤0,05%), but in the second evaluations no differences were noted between treatments (Figure 2A).

Biological activity. The biological activity of the soil was evaluated by the enzyme ß-glucosidase during two cycles 2014/15 and 2015/16, nevertheless no statistical differences were verified (T test – LSD, p>0,05%) in both years (Figure 2B).

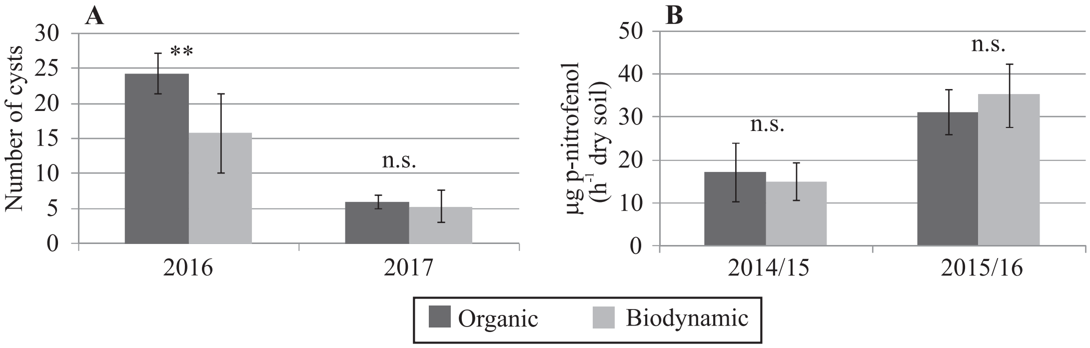

Figure 2 - Number of ground-pearl cysts of the soil (*Eurhizococcus brasiliensis*) in two samples of BRS Carmem grapevines (A) and biological activity of the soil with the enzyme ß-glucosidase in the cycles 2014/15 and 2015/16 (B). Guarapuava-PR, 2017. Differ by the T test - LSD ** ($p \leq 0,05$), n.s. no significant.

DISCUSSION

After one year of the treatments, the chemical analysis of the soil showed the highest content of K and H+Al in the two depths and Cu in one depth for the biodynamic treatment (Table 3). Some studies have showed that biodynamic organic composts have lower losses of nutrients compared to those that do not receive the preparations (TURINEK, et al., 2009). Miklós et al. (2000) found higher potassium and calcium content in the biodynamic compost prepared with sugarcane bagasse and ash. Reeve (2003), in a study with biodynamic compost preparations, observed that in most cases the biodynamic compost had higher cations content, total N and organic matter concentration than the untreated compost, higher respiration rate and a more even and prolonged heating period, although the statistical difference was only observed for K. Potassium is an enzymatic activator essential for photosynthesis and respiration, as well as enzymes that produce starch and proteins and, as a consequence, improves the growth and development of plants (BAVARESCO et al., 2010).

Results of collecting insects with traps and soil monoliths not showed difference between treatments. The collection of insects with monoliths showed an interesting trend, where the highest values of Simpson's Dominance and lower Shanon's Diversity found indicate that the biodynamic treatment may have generated the selection of some species in the row and lower diversity (Figure 1). More organisms were also found in the soil with biodynamic treatment, but due to the high variability of values there was no significant difference. Highlight in both cycles for the greater number of termites and earthworms in the cultivation row, for the biodynamic treatment and, greater number of ants for the organic treatment in the second cycle (Table 3 and 4).

The microorganisms have a large role in several soil stages, such as organic matter decomposition and/or nutrient cycling, as well as directly influencing the soil biological balance (SANGINGA et al., 1992; FLIEßBACH et al., 2007). The management and the soil culture system can modify the density and diversity of the most frequent groups of organisms (BARETTA et al., 2003; SILVA et al., 2006). According to Blanchart et al. (2004), the preservation of vegetative cover and decomposing organisms can contribute to improve the sustainability of the agricultural system, being the fauna of the soil, at the same time, transforming agent, reflecting in the physical, chemical and biological characteristics of the soils.

Earthworms are highly sensitive to their environment and can be indicators of small positive or negative changes in soil quality. Pfeiffer (1983) in a study with biodynamic preparations found that earthworms migrated to the soil treated with the preparations. In a second experiment, more earthworms migrated to the soil sprayed with the preparation of valerian (507) compared to the non-sprayed control soil. Reeve (2003), working with biodynamic management, found 28% more earthworms in biodynamic batches than in controls, although there was no difference between treatments due to the high variability of results. However, in an experiment in which earthworms were allowed to migrate to soil sprayed with biodynamic preparations or soil sprayed with water, a significant difference was found in the preference of earthworms for biodynamic treatment.

Among the insects that attack the vine, the ground-pearl (*Eurhizococcus brasiliensis*), stands out due to the difficult control and severe damage. *E. brasiliensis* attacks the roots of the vines, causing a progressive loss of vigor, which can lead to the death of the plant (HICKEL et al., 2001). The use of biodynamic preparations had decreased the number of ground-pearl cysts in the vine's root, in the first collection performed in 2016 (Figure 2A). Biodynamic preparations produce a compound with lower nitrogen loss and greater nutrient retention capacity, stimulating the organisms present in the compound (KLETT, 2012; FLEIßBACH et al., 2007). According to Carpenter-Boggs et al (2000b), biodynamic preparations have an effect on the compost as a biostimulant or as a microbial inoculant. The biodynamic compost is treated with specially fermented plant inoculants (prepared 502-507) and there is evidence that the preparations alter the microbial community and the final product of the compound. The increase of faunal biodiversity (macro and microbiological) can be used for biological control of insects in vineyards (ALTIERI & NICHOLLS, 2004). Compost preparations stimulate soil formation processes, resulting in the orderly decomposition of the dead organic matter and its transformation into humus (WISTINGHAUSEN, 2000).

Microorganism enzymes have an essential participation in processes related to soil quality. These compounds degrade complex organic molecules in simple molecules that can be assimilated by the plants (MOREIRA & SIQUEIRA, 2006). The enzymatic activity of soil microorganisms is responsive to changes in the soil management system, including the effects produced by the management of crop residues, fertilizer application, soil compaction, tillage (plowing, harvesting or no-tillage) and crop rotation. Therefore, the evaluation of the enzymatic activity can reflect the positive and negative effects that these practices cause on the soil (DICK et al., 1996).

Reeve et al. (2010) demonstrated that the compound treated with the biodynamic preparations presented higher dehydrogenase activity than the untreated ones (control), demonstrating greater microbiological activity. However, according to our results, no difference was found between the treatments for the β-glucosidase enzyme in the cycles analyzed (Figure 2B). Sinsabaugh et al. (1993) reported that enzymes that degrade lignocellulose, such as glucosidase and phenol oxidase, are regulated by the availability of substrate. The management of the spontaneous plants and maintenance of the green mass in the present work were done in the same way, which may have contributed to the maintenance of the substrate in the two treatments.

New analyzes and the continuity of long-term work can demonstrate the efficiency of organic management and biodynamic preparations in the macro and microfauna of the soil.

CONCLUSION

Soil managed with biodynamic preparations presented higher K and H+Al content in the two depths. Moreover, it showed copper content and lower base saturation at depth 0-10 cm. The number of ground-pearl cysts in the root of plants managed organically was higher in the first year. Soil collection for macrofauna analysis not showed statistical difference between organic and biodynamic treatment in the first year, as well, no differences were observed for ß-glucosidase enzyme activity.

REFERENCES

ALTIERI, M.; NICHOLLS, C. L. Biodiversity and pest management in agroecosystems. 2 ed. Binghamton: Food Products Press, 2004.

ANDERSON, J. M.; INGRAM, J. S. I. Tropical soil biology and fertility: a handbook of methods. 2ed. Wallingford: CAB International, 1993. 221p.

BARETTA, D.; SANTOS, J. C. P.; MAFRA, Á. L. Fauna edáfica avaliada por armadilhas de catação manual afetada pelo manejo do solo na região oeste catarinense. Revista de Ciência Agroveterinárias, v.2, n.2, p.97-106, 2003.

BAVARESCO, L, GATTI, M. y FREGONI, M. 2010. Nutritional deficiencies. In Methodologies and results in grapevine research; Springer: Berlin, Germany, pp. 165-191.

BLANCHART, E.; ALBRECHT, A.; BROWN, G.G.; DECAËNS, T.; DUBOISSET, A.; LAVELLE, P.; MARIANI, L.; ROSSE, E. Effects of tropical endogeic earthworms on soil erosion: a review. Agriculture, Ecosystems and Environment, v.104 p.303-315, 2004.

BURNS, K.N.; BOKULICH, N.A.; CANTU, D.; GREENHUT, R.F.; KLUEPFEL, D.A.; O'GEEN, A.T.; STEENWERTH, K.L. Vineyard soil bacterial diversity and composition revealed by 16S rRNA genes: Differentiation by vineyard management. Soil Biology and Biochemistry, v.103, pp. 337-348, 2016.

CARPENTER-GOGGS, L.; KENNEDY, A.C.; REGANOLD, J.P. Organic and biodynamic management: Effect on soil biology. Soil Science American Journal, v. 64, p. 1651-1658, 2000a.

CARPENTER-GOGGS, L.; REGANOLD, J.P.; KENNEDY, A.C. Effects of biodynamic preparations on compost development. Biological Agriculture and Horticulture, v. 17, p. 313-328, 2000b.

DICK, R.P.; BREACKWELL, D.P.; TURCO, R.F. Soil enzyme activities and biodiversity measurements as integrative microbiological indicators. In: DORAN, J.W.; JONES, A.J. Methods for assessing soil quality. Madison: SSSA, 1996. p. 247-271.

DIVES – Diversidade de Espécies. Ecological Software. Versão 3.0.7. Disponível em: <http://dives.ebras.bio.br/> Acesso em 20 jun 2015.

FAUST, S.; HEINZE, S.; NGOSONG, C.; SRADNICK, S.; OLTMANNS, M.; RAUPP, J.; JOERGENSEN, R.H. Effect of biodynamic soil amendments on microbial communities in comparison with inorganic fertilization. Applied Soil Ecology, v.114, pp. 82-89, 2017.

FLIEßBACH, A., OBERHOLZER, H.R., GUNST, L., and MÄDER, P. Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. Agriculture, Ecosystems and Environment v.118, p.273-284, 2007.

FERREIRA, D. F. Sisvar: a Guide for its Bootstrap procedures in multiple comparisons. Ciência. agrotécnica. [online]. 2014, vol.38, n.2 [citado 2015-10-17], pp. 109-112. Disponivel em: ISSN 1413-7054.<http://dx.doi.org/10.1590/S1413-70542014000200001>.

HICKEL, E.R.; PERUZZO, E.L.; SCHUCK, E. Control of the Ground-Pearl Eurhizococcus brasiliensis (Hempel) (Homoptera: Margarodidae) With Chemigation. Neotropical Entomology, v.30, n.1, pp.125-132, 2001.

IAPAR. Instituto Agronômico do Paraná. Dados meteorológicos estação Guarapuava, Paraná de 1976-2016. Disponível em:<http://www.iapar.br/arquivos/ Image/ monitoramento/Medias_ Historicas/ Guarapuava.htm> Acesso em 04 mai 2017.

JOVCHELEVICH, P.; VIDAL, A. Calendário Biodinâmico. Associação Brasileira de Agricultura Biodinâmica, Botucatu: Destak, 2016. 195p.

KOEPF, H.; PETTERSSON, B. D.; SCHUMANN, W. Agricultura biodinâmica. São Paulo: Nobel, 1983. 316 p.

LOPES, J.; CONCHON, I.; YUZAWA, S.K. & KÜHNLEIN, R.R.C. Entomofauna do Parque estadual Mata do Godoy: II. Scarabaeidae (Coleoptera) coletados emarmadilhas de solo. Semina Ciência Biologica/Saúde, v. 15, p. 121-127, 1994.

MAPA, 2019. Alimentos orgânicos renderam R$ 4 bilhões a produtores brasileiros em 2018. Disponível em: http://www.agricultura.gov.br/noticias/mercado-brasileiro-de-organicos-fatura-r-4-bilhoes. Acesso em: 14 de maio de 2019.

MAPA, Instrução normativa 46/2011. Disponível em:<http://www.agricultura. gov.br/arq_editor/file/Desenvolvimento_Sustentavel/Organicos/Legislacao/Nacional/Instrucao_Normativa_n_0_046_de_06-10 2011_regulada_pela_IN_17.pdf> Acessado em: 10 jan. 2016.

MAPA. Ministério da Agricultura, Pecuária e Abastecimento. Número de produtores orgânicos cresce 51,7% em um ano. Disponível em: <http://www.agricultura.gov.br/comunicacao/noticias/2015/03/numerodeprodutoresorganicoscresce51porcento-emum-ano> Acesso em: 07 dez. 2016.

MARTIN, K.R.; RASMUSSEN, K.K. comparison of sensory qualities of geographically paired organic and conventional red wines from the Southwestern US with differing total polyphenol concentrations: A randomized pilot study. Food and Nutrition Sciences, 2, p. 10, 2011.

MIKLÓS, A. A. W.; KARALL, J. M.; PIEDADE, S. M. S.; BOCHI, U. Avaliação dos efeitos dos preparados biodinâmicos sobre as perdas de nutrientes na compostagem de resíduos da indústria sucro-alcooleira. Agricultura Biodinâmica. Botucatu, Ano 18, n. 85. p. 9-12. 2000.

MOREIRA, F.M.S.; SIQUEIRA, J.O. Microbiologia e bioquímica do solo. 2. ed. Lavras: UFLA, 2006.729p.

MULERO, J.; ZAFRILLA, P.; CAYUELA, J.M.; MARTINEZ-CACHA, A. PARDO, F. Antioxidant activity and phenolic compounds in organic red wine using different winemaking techniques. Journal of Food Science, v. 76, n. 3, pp. 436-440, 2011.

PARPINELLO, J.P.; RICCI, A.; ROMBOLÀ, A.D. Nigro, G. VERSARI, A. Comparison of Sangiovese wines obtained from stabilized organic and biodynamic vineyard management systems. Food Chemistry, v. 283, p. 499-507, 2019.

PAVAN, M.A.; BLOCH, M.F.; ZEMPULSKI, H.C.; MIYAZAWA, M.; ZOCOLER, D.C. Manual de análise química do solo e controle de qualidade. Londrina, Instituto Agronômico do Paraná, 1992. 40p. (Circular, 76)

PIVA, R., R. V. BOTELHO, P. C. G. LIMA, A.D. ROMBOLÀ. Development, physiology and occurrence of downy mildew in grapevine cv. BRS Margot treated with biodynamic preparations. Revista de Ciências Agrárias, v.42, n.2, p.472-482, 2019.

RAUPP, J. and KÖNIG, U.J. Biodynamic preparations cause opposite yield effects depending upon yield levels. Biological Agriculture and Horticulture, v.13 p.175-188, 1996.

REEVE, J. R. Effects of biodynamic preparations on soil, winegrape and compost quality on a Califórnia vineyard. (Master of Science). Washington State University. 2003, 94p.

REEVE, J.R.; CARPENTER-BOOGS, L.; REGANOLD, J.P.; YORK, A.L.; BRINTON, W.F. Influence of biodynamic preparations on compost development and resultant compost extracts on wheat seedling growth. Bioresource Technology, v.101, p. 5658-5666, 2010.

REGANOLD, J. P.; PALMER, A. S. Significance of gravimetric versus volumetric measurements of soil quality under biodynamic, conventional, and continuous grass management. Journal of Soil and Water Conservation, v. 50, n.3, p. 298-305, 1995.

SANGINGA, N.; MULONGOY, K.; SWIFT, M.J. Contribution of soil organisms to the sustainability and productivity cropping systems in the tropics. Agriculture Ecosystems and Environment, v.41, p.135-152, 1992.

SHANNON, C.E. A mathematical theory of communication. The Bell Sysemt Technical Journal. v. 27, p.379-423, 623-656. 1948.

SILVA, R.F.; AQUINO, A. M.; MERCANTE, F. M. GUIMARÃES, M. F. Macrofauna invertebrada do solo sob diferentes sistemas de produção em Latossolo da Região do Cerrado. Pesquisa Agropecuária Brasileira, Brasília, v.41, p.697- 704, 2006.

SIMPSON, E. H. Measurement of diversity. Nature, v.163, p.688, 1949.

SINSABAUGH, R. L.; ANTIBUS, R. K.; LINKINS, A. E.; McCLAUGHERTY, C. A.; RAYBURN, L.; WEILAND, T. Wood decomposition: nitrogen and phosphorus dynamics in relation to extracellular enzyme activity. Ecology, v.74, p.1586-1593, 1993.

STEINER, R. Fundamentos da Agricultura Biodinâmica: vida nova para a terra. 3ed. São Paulo: Antroposófica, 2010. 239p.

TOMICH, T.P.; BRODT S.; FERRIS, H. et al. Agroecology: a review from a global-change perspective. Annual Review of Environment and Resources, v.36, n. 1, 2011.

TURINEK, M., S. GROBELNIK-MLAKAR, M. BAVEC, and F. BAVEC. Biodynamic agriculture research progress and priorities. Renewable Agr. Food Systems, v.24, p.146-154, 2009.

WISTINGHAUSEN, C. V.; SCHEIBE, W.; HEILMANN, H.; WISTINGHAUSEN, E. V.; KÖNING, U. J. Manual para uso dos Preparados Biodinâmicos. São Paulo Editora Antroposófica; Botucatu, SP: Associação Brasileira de Agricultura Biodinâmica, 2000, 77p.

WREGE, M.S.; STEINMETZ, S.; REISSER JUNIOR, C.; ALMEIDA, I.R. Atlas climático da Região Sul do Brasil: Estados do Paraná, Santa Catarina e Rio Grande do Sul. 1. Pelotas: Embrapa Clima Temperado; Colombo: Embrapa Florestas, 2011. 336p.

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