BIOLOGICAL NEMATICIDES ASSOCIATED WITH POULTRY LITTER IN THE CONTROL OF NEMATODES IN SOYBEAN AND SECOND CORN CROP[1]

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ABSTRACT - Alternative management measures have been used to reduce nematode population levels in affected areas. In this perspective, the objective was to evaluate the efficiency of nematicides based on fungus and bacterium, associated with poultry litter applied via ground in the management of *Pratylenchus brachyurus* and *Heterodera glycines* in soybean and corn crops in succession. The experiment was conducted in the 2018/19 growing season in the municipality of Ipameri– GO (-17°34'55.58"S -48°12'02.35"O) in naturally infested field, arranged in a randomized block design, with 10 treatments and 4 replicates, being: T1- Witness/ control, T2- Poultry litter, T3- *P. lilacinum* + *T. harzianum*, T4- *B. subtilis* + *B. licheniformis*, T5- *P. chlamydosporia*, T6- Abamectina, T7- *P. lilacinum* + *T. harzianum* + Poultry litter, T8- *B. subtilis* + *B. licheniformis* + Poultry litter, T9- *P. chlamydosporia* + Poultry litter, T10- Abamectina + Poultry litter. The poultry litter was added in the soil 10 days before planting. The plots were composed of 6 lines of 6 m, with a spacing of 0.5 m. In the soybean crop at 45 and 90 days after sowing (DAS), the fresh weight of the roots (MFR), nematological variables and productivity were evaluated. In corn, only nematological variables were evaluated at 60 DAS. The treatments using *P. lilacinum* + *T. harzianum* and *B. subtillis* + *B. licheniformes* increased the MFR and reduced the number of *P. brachyurus* and *H. glycines* at the root. *P. chlamydosporia* associated with poultry litter increased in productivity in soybean plants.

Keywords: *Glycine* max. *Zea mays*. Soybean Cyst nematode. Root lesion nematode. Biological control. Cultural control.

NEMATICIDAS BIOLÓGICOS ASSOCIADOS A CAMA DE FRANGO NO CONTROLE DE NEMATOIDES NA SOJA E MILHO

RESUMO - Medidas alternativas de manejo têm sido utilizadas buscando reduzir níveis populacionais de nematoides em áreas afetadas. Nesta ótica, objetivou-se avaliar a eficiência de nematicidas biológicos a base de fungos e bactérias, associados a cama de aviário aplicada via solo no manejo de *Pratylenchus brachyurus* e *Heterodera glycines* na cultura da soja e milho em sucessão. O experimento foi conduzido na safra 2018/19 no município de Ipameri – GO (-17°34'55.58"S -48°12'02.35"O) em campo naturalmente infestado, disposto em delineamento de blocos casualizados, empregando 10 tratamentos e 4 repetições, sendo: T1- Testemunha, T2- Cama de frango, T3- *P. lilacinum* + *T. harzianum*, T4- *B. subtilis* + *B. licheniformis*, T5- *P. chlamydosporia*, T6- Abamectina, T7- *P. lilacinum* + *T. harzianum* + Cama de frango, T8- *B. subtilis* + *B. licheniformis* + Cama de frango, T9- *P. chlamydosporia* + Cama de frango, T10- Abamectina + Cama de frango. A cama de frango foi adicionada ao solo 10 dias antes do plantio. As parcelas foram compostas por 6 linhas de 6 m, com espaçamento de 0,5 m. Na cultura da soja aos 45 e 90 dias após a semeadura (DAS) avaliou-se a massa fresca das raízes (MFR), variáveis nematológicas e produtividade. No milho avaliou-se apenas as variáveis nematológicas aos 60 DAS. Os tratamentos empregando *P. lilacinum* + *T. harzianum* e *B. subtillis* + *B. licheniformes* elevaram a MFR e reduziram o número de *P. brachurus* e *H. glycines* na raiz. *P. chlamydosporia* associada a cama de frango promoveram incremento de produtividade em plantas de soja.

Palavras-chave: *Glycine* max. *Zea mays*. Nematoide do cisto da soja. Nematoide das lesões radiculares. Controle biológico. Controle cultural.

INTRODUCTION

In the Midwest and Northeast of Brazil, the cultivation of soybeans and corn in succession is widely practiced by farmers. About 100 species of nematodes, included in 50 genera, have been associated with soybean worldwide (DIAS et al., 2010). In Brazil, corn can be affected by 40 species, covering about 12 genera (MIRANDA; MIRANDA, 2018). The most important nematodes are: *Meloidogyne incognita*, *M. javanica*, *Pratylenchus brachyurus* and *Heterodera glycines* (CORTE et al., 2014).

In terms of commercial damage, it is estimated that the losses caused by nematodes exceed 80 billion dollars (FERRAZ; BROWN, 2016). According to Machado (2015), the economic damage faced by Brazil in the face of these pathogens can reach R$ 35 billion per agricultural year. It is believed that, of this amount only in the soybean crop, losses of R$ 16.2 billion will occur.

Nematodes cause limitations in the absorption of water and mineral salts from the soil solution, reflecting a decrease in the root system and aerial part, wilted and / or chlorotic leaves, and consequently a reduction in productivity (DIAS et al., 2010). Alternative management measures have been used in order to reduce nematode populations, such as: use of chemical and biological nematicides, organic compounds, resistant plants or with low reproduction factor (RF) and rotation with non-host crops (SILVA et al., 2018).

The use of nematicides via seed treatment or application in planting furrows is a technique that is widespread among farmers, due to the practicality of application (INOMOTO, 2011). In Brazil, there are five biological agents and six chemical molecules capable of controlling nematodes in soybeans and corn (Abamectin, Fluensulfone, Tiodicarb, Cadusafós, Fluopyram, Thiophanate-methyl + Fluazinam, *Bacillus* sp., *Trichoderma harzianum*, *Pasteuria nishizawae*, *Purpureocillium oniachilporchyliachilia*) (AGROFIT, 2020).

Nematophagous fungi such as *Purpureocilum lilacinum* and *Pochonia chlamydosporia* have the ability to suppress nematode reproduction by destroying the egg embryo, colonizing females and cyst (SILVA, 2015a). The fungus *T. harzianum*, in addition to acting on eggs and juveniles of nematodes, manages to activate plant defense mechanisms (LIMA, 2019). Likewise, some bacteria of the genus *Bacillus* sp. exert nematicidal action on early stages of nematodes by releasing antibiotic compounds, in addition to promoting the development of cultivated plants (SILVA, 2015b).

Pasteuria nishizawae is an obligatory and specific parasite bacterium of *H. glycines*. Its parasitism begins with the adherence of the endospores to the cuticle of second-stage juveniles, where the penetration of the germ tube into the nematode's body can prevent its penetration into the roots. Infected females and cysts are colonized by sporangia and mature endospores, which are released into the soil after the nematode disintegrates (VICENTE, 2014).

When poultry litter is added to the soil it releases toxic compounds to the nematodes (ammonia, humic and fulvic acids) during its decomposition process, provides nutrients to the plants and increases the organic matter content in the soil, favoring the development of antagonistic microorganisms (KOENNING et al., 2003). The interaction between poultry litter and biological control agents is promising, since two nematode control techniques are employed, decreases the use of chemicals and offers a purpose to an agro-industrial residue in a sustainable and environmentally safe way.

Therefore, the present study aimed to evaluate the efficiency of biological nematicides based on fungi and bacteria, associated with the poultry bed in the management of *Pratylenchus brachyurus* and *Heterodera glycines* in soybean and corn crops in succession.

MATERIALS AND METHODS

The assay was conducted in the 2018/19 harvest in the municipality of Ipameri-Go, located under the geographical coordinates -17°34'55.58" S - 48°12'02.35" O, in a commercial area naturally infested with *P. brachyurus* and *H.glycines* race 6, in which the producer practices the cultivation of soy and corn in succession. The experiment was arranged in a randomized block design in a 5 x 2 factorial scheme, with 4 replications (Table 1).

Two plantings were carried out, first sowing soybean (Desafio RR) and then corn (AG8061 PRO2) in succession. The poultry litter was added to the soil ten days before sowing soybeans, in the amount of 4 Mg.ha^{-1} according to preliminary dose studies. The nematicides were added to the soybean and corn seeds in a plastic bag previously identified, following the doses recommended in the package leaflet by the manufacturers. Planting took place shortly after seed treatment. Each experimental plot contained six planting lines six meters long, spaced 0.5 m apart, making up a useful area of 18 m^2, where the 1st and 6th lines were considered as borders, in the 2nd and 5th lines soil and root collections were carried out, and at the 3rd and 4th were preserved to evaluate productivity.

The analysis of the initial nematode population in the soil, chemical analysis of the organic compost and soil fertility was performed (Table 2). Fertilization and other cultural treatments were carried out according to the standard of the producer, used during the crop cycle. Nematological evaluations (*P. brachyurus*/10g of root and 100 cm^3

of soil, females of *H. glycines*/g of root, viable and non-viable cyst per 100 cm³ of soil, eggs/female and eggs/cyst of *H. glycines*) and fresh root mass was carried out at 45 and 90 days after sowing (DAS) for soybean and at 60 DAS for corn. Yield was evaluated only at the end of the soybean crop (first crop).

Table 1. Treatments used in the experiment for the cultivation of soybean and safrinha corn.

	Treatments	Doses*
1.	Control	-
2.	Poultry litter	4**
3.	*Purpureocilum lilacinum + Trichoderma harzianum*	30 + 15
4.	*Bacillus subtilis + Bacillus licheniformis*	20 + 20
5.	*Pochonia chlamydosporia*	56
6.	Abamectina	50
7.	*P. lilacinum + T. harzianum* +Poultry litter	30 + 15 + 4**
8.	*B. subtilis + B. licheniformis* + Poultry litter	20 + 20 + 4**
9.	*P. chlamydosporia* +Poultry litter	56 + 4**
10.	Abamectina + Poultry litter	50 + 4**

*g i.a/100 kg of seeds.
**Mg.ha⁻¹.

Table 2. Result of soil and poultry litter analysis, with the respective nutrient contents.

Poultry litter			Soil analysis		
Nutrients		Content	Components		Content
K$_2$O		3.30	Clay		550.4
P$_2$O$_5$		2.38	Silt	---g/kg---	200
N		3.40	Sand		249.6
Ca	---%---	2.21	M.O		6.10
Mg		0.54	V	---%---	72.26
S		0.77	P		0.506
B		55	K	-- mg/dm³ --	232
Cu		108	Ca		5.7
Fe	---mg/kg---	364	Mg		1.8
Mn		328	H+Al	-- cmolc/dm³ --	3.1
Zn		310	CTC		11.3
-		-	pH	-- Water --	6.33

The specimens of *P. brachyurus* were extracted from plant tissue using the method proposed by Coolen and D'Herde (1972) and from the soil by Jenkins (1964). The extraction of females and cyst were performed based on the methodology proposed by Tihohod (1993) and (ANDRADE; ASMUS; SILVA, 1995), respectively. Yield was evaluated when 95% of soybean plants reached full maturity (stage R8) with grains presenting about 15% moisture (OLIVEIRA JUNIOR et al., 2016). All plants were collected in 5 m from the two central lines of each plot for the evaluation.

Nematological and fresh root mass data were subjected to multivariate analysis of variance (MANOVA). From this, it was evaluated whether there was a multivariate difference between the treatments studied by means of the Pillai's Trace test, with a level of significance of 5%. After evidencing a significant difference between treatments, canonical discriminating variables were constructed to visualize the behavior of treatments. This was done using the MANOVA residual variance and treatment matrices. The first two canonical discriminating variables were presented in a biplot chart and to identify significant differences between treatments, ellipses of 95% confidence were built for the mean scores of both (PILLAI, 1955; JOHNSON; WICHERN, 1999).

The productivity data were subjected to analysis of variance (ANOVA) and the treatment means were compared using Fisher's LSD test at 5% significance level. The percentage of increase or decrease in productivity in relation to the control, was obtained from the calculation $\left(\frac{Treatment}{Control} \times 100\right) - 100$. All statistical analyzes were performed using software R version 3.5.3 (R CORE TEAM, 2019).

RESULTS AND DISCUSSION

The result of the multivariate analysis of variance (MANOVA), analysis for the three periods analyzed in soybean and at 60 DAS in maize crop is shown in Table 3.

The previous evaluation of the nematode population present in the area showed that the number of *P. brachyurus* and cysts of *H. glycines* were found to be elevated in the soil, both presenting the largest vectors in the graph (Figure 1). It is also noted that the behavior of the reliable ellipses remained very close and overlapping, which indicates a good distribution of the nematodes in the experimental area, allowing the conduction of the test on site.

Table 3. Result of multivariate analysis of variance (MANOVA) at 0, 45 and 90 DAS to soybean and 60 DAS to maize.

|	Variation source	Degrees of freedom	Pillai	Approx F num	Df	denDf	p-value
Soybean 0 DAS	Treatment	9	0.79989	1.2119	27	90	0.2475
	Residual	30					
Soybean 45 DAS	Variation Source	Degrees of freedom	Pillai	Approx F num	Df	denDf	p-value
	Treatment	9	2.3761	1.0402	90	261	0.3987
	Residual	30					
Soybean 90 DAS	Variation source	Degrees of freedom	Pillai	Approx F num	Df	denDf	p-value
	Treatment	9	2.5423	1.1417	90	261	0.2114
	Residual	30					
Maize 60 DAS	Variation source	Degrees of freedom	Pillai	Approx F num	Df	denDf	p-value
	Treatment	9	2.5317	1.8886	63	210	<0.001
	Residual	30					
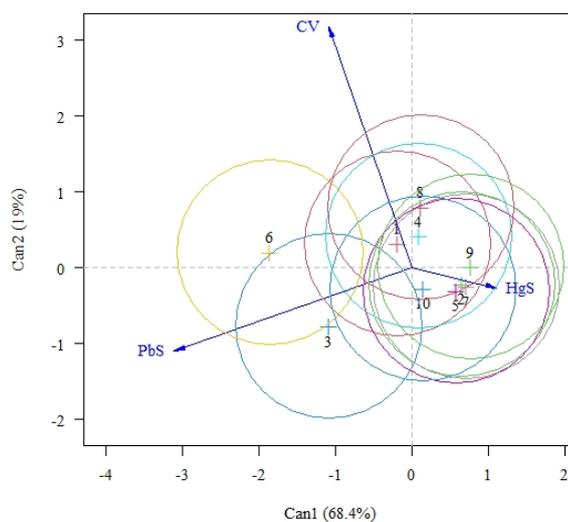
Figure 1. Biplot containing mean scores of canonical discriminating variables, under the effect of the initial population in the plots where the treatments were applied, with ellipses of 95% confidence, analyzed before the installation of the test. Pbs: *P. brachyurus*/100 cm^3 of soil, HgS: *H. glycines*/100 cm^3 of soil, CV: Viable cyst/100 cm^3 of soil. T1- Control, T2- Poultry litter, T3- *P. lilacinum* + *T. harzianum*, T4- *B. subtilis* + *B. licheniformis*, T5- *P. chlamydosporia*, T6- Abamectina, T7- *P. lilacinum* + *T. harzianum* + Poultry litter, T8- *B. subtilis* + *B. licheniformis* + Poultry litter, T9- *P. chlamydosporia* + Poultry litter, T10- Abamectina + Poultry litter.

At 45 days after sowing (DAS), the use of isolated chicken litter and the association of *P. lilacinum* and *T. harzianum* with the organic compound were the ones that came closest to the variable vector (MFR), when compared to the other treatments (Figure 2).

The variable *P. brachyurus* per 10 g of root (PbR) was reduced by positioning the treatment with poultry litter associated with *P. lilacinum* and *T.*

harzianum at 45 DAS. All treatments reduced the density of *P. brachyurus* in the root system in relation to the control. The use of poultry litter alone reduced the amount of females (FM) in the root system at 45 DAS; however, the combination of organic compound with Abamectin did not affect the number of females, viable and unviable cyst of *H. glycines* for the same observed time.
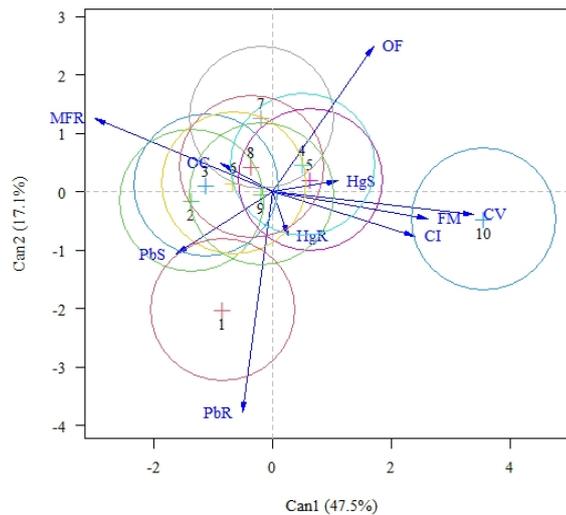

Figure 2. Biplot containing mean scores of canonical discriminating variables under the effect of 10 treatments with 95% confidence ellipses, for nematological assessment of soil and root at 45 days after sowing (DAS) in soybean. MFR: Fresh root mass, PbR: *P. brachyurus*/10g of root, Pbs: *P. brachyurus*/100 cm³ of soil, FM: Female/g of root, HgR: Juvenile of *H. glycines*/10 cm³ of root, HgS: Juvenile of *H. glycines*/100 cm³ of soil, CV: Viable cyst/100 cm³ of soil, CI: Unviable cyst/100 cm³ of soil, OF: Eggs/female, OC: Eggs/cyst. T1- control, T2 - poultry litter, T3- *P. lilacinum* + *T. harzianum*, T4- *B. subtilis* + *B. licheniformis*, T5- *P. chlamydosporia*, T6- Abamectina, T7- *P. lilacinum* + *T. harzianum* + poultry litter, T8- *B. subtilis* + *B. licheniformis* + poultry litter, T9- *P. chlamydosporia* + poultry litter, T10- Abamectin + poultry litter.

t 90 DAS it is possible to observe that Abamectin alone, *P. lilacinum* + *T. harzianum* and *B. subtilis* + *B. licheniformis*, both biological associated with poultry litter, showed better development in the root system of soybean plants and better efficacy in reducing *P. brachyurus* (PbR) and *H. glycines* (HgR) at the root, in relation to the positioning of biological agents in isolation (Figure 3). The use of Abamectin + poultry litter remained close to the female variables in the root (FM), viable cyst (CV) and unviable (CI) of *H. glycines* in the soil, at 90 DAS.

The evaluated treatments did not differ statistically from the control in relation to the productivity of the soybean crop. However, the use of *P. chlamydosporia* alone presented an increase of 1% in relation to the control. When *P. chlamydosporia* was associated with chicken litter, it showed an even greater increase, with 8.8% in relation to soybean plants that did not receive treatment (Table 4).

In the cultivation of safrinha corn, it is possible to observe at 60 DAS that the association of

B. subtilis + *B. licheniformis* with poultry litter, the increase in (MFR) was superior to the treatment with *B. subtilis* + *B. licheniformis* isolated. The lowest number of *P. brachyurus* in the root (PbR) was seen with the use of *P. chlamydosporia*, compared to the other treatments. Abamectin + poultry litter remained close to the vector of the viable (CV) and non-viable (CI) variables of *H. glycines* in the soil (Figure 4).

The release of nutrients such as nitrogen, phosphorus and potassium, an increase in the content of organic matter and an improvement in the physical-chemical properties of the soil caused by the chicken litter, promoted better penetration and development of the root system in soybeans and corn. A study conducted by Scherer (1995) reveals that the fresh mass of corn roots that received fertilizer with poultry litter, were benefited due to the ability of poultry manure to increase the exchange of cations and the availability of nutrients for plants. Another factor that favored the increase in fresh mass of root plants, was the suppression of

nematodes caused by the direct action of the poultry litter, through the release of ammonia and toxic humic acids to the nematodes and by the interaction with biological control agents through the indirect availability of organic carbon in the soil. In parallel to the results found in this work, Santos et al. (2019) observed that the treatment of soybean seeds with nematophagous fungi, in addition to promoting greater accumulation of fresh mass at the roots, reduced by up to 68.30% the number of *P. brachyurus* in the root system, in relation to the control.

In addition to the direct action on nematodes through the release of humic acids and toxic gases during the organic matter decomposition process, the availability of organic carbon in the soil may have favored the growth and establishment of the fungi *P. lilacinum* and *T. harzianum* and the bacteria of the genus *Bacillus* sp. This synergism possibly suppressed populations of *P. brachurus* and *H. glycines* in crops used at field level. Al-Hazmi et al. (2019) analyzing the effect of different concentrations of humic acid on populations of *M. javanica*, found that the exposure of eggs and juveniles (J2) to the highest concentration of the compound, inhibited hatching by up to 59.8% and promoted a mortality rate of J2 by 89.5%, respectively. Confirming the nematostatic effect of the poultry litter found in this work.
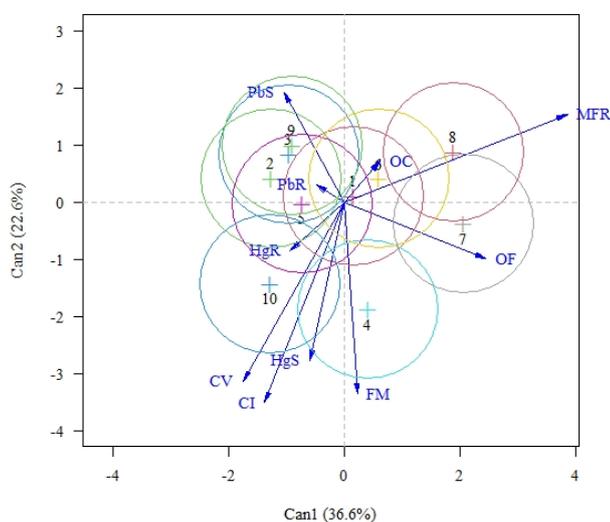

Figure 3. Biplot containing mean scores of canonical discriminating variables under the effect of 10 treatments with 95% confidence ellipses, for nematological assessment of soil and root at 90 days after sowing (DAS) of soybean. MFR: Fresh root mass, PbR: *P. brachyurus*/10g of root, Pbs: *P. brachyurus*/100 cm³ of soil, FM: Female/g of root, HgR: Juvenile of *H. glycines*/10g of root, HgS: Juvenile of *H. glycines*/100 cm³ of soil, CV: Viable cyst/100 cm³ of soil, CI: Unviable cyst/100 cm³ of soil, OF: Eggs/female, OC: Eggs/cyst. T1- Control, T2- poultry litter, T3- *P. lilacinum* + *T. harzianum*, T4- *B. subtilis* + *B. licheniformis*, T5- *P. chlamydosporia*, T6- Abamectin, T7- *P. lilacinum* + *T. harzianum* + poultry litter, T8- *B. subtilis* + *B. licheniformis* + poultry litter, T9- *P. chlamydosporia* + poultry litter, T10- Abamectin + poultry litter.

Table 4. Effect of treatments on productivity (kg/ha⁻¹) and percentage of increase in soybean plants.

	Treatments	Productivity (kg/ha⁻¹)	Increment/Reduction (%)
1.	Control	1952.0 ab	0
2.	Poultry litter	1853.7 ab	-5.0
3.	*P. lilacinum* + *Trichoderma harzianum*	1812.3 ab	-7.1
4.	*Bacillus subtilis* + *Bacillus licheniformis*	1725.3 ab	-11.6
5.	*Pochonia chlamydosporia*	2062.7 b	1.0
6.	Abamectina	1567.0 a	-19.7
7.	*P. lilacinum* + *T. harzianum* + poultry litter	1564.5 a	-19.8
8.	*B. subtilis* + *B. licheniformis* + poultry litter	1802.6 a	-7.6
9.	*P. chlamydosporia* + poultry litter	2125.3 b	8.8
10.	Abamectina + poultry litter	1735.9 ab	-11.0
	CV (%)	18.46	
	p-Value	0.3102	

Means followed by the same lower case letter in the column are not differentiated by the LSD test at 5% significance.
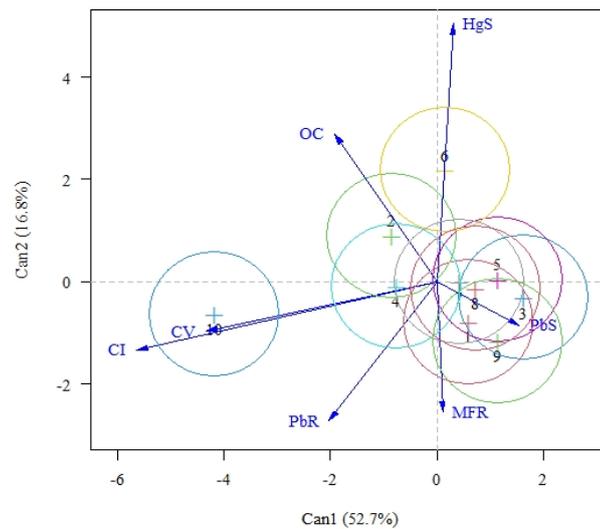
Figure 4. Biplot containing mean scores of canonical discriminating variables under the effect of 10 treatments with 95% confidence ellipses, for nematological assessment of soil and root at 60 days after sowing (DAS) of safrinha corn. MFR: Fresh root mass, PbR: *P. brachyurus*/10g of root, Pbs: *P. brachyurus*/100 cm^3 of soil, HgS: Juvenile of *H. glycines*/100 cm^3 of soil, CV: Viable cyst/100 cm^3 of soil, CI: unviable cyst/100 cm^3 of soil, OC: eggs/cyst. T1- control, T2- poultry litter, T3 - *P. lilacinum + T. harzianum*, T4- *B. subtilis + B. licheniformis*, T5- *P. chlamydosporia*, T6- Abamectina, T7- *P. lilacinum + T. harzianum* + poultry litter, T8- *B. subtilis + B. licheniformis* + poultry litter, T9- *P. chlamydosporia* + poultry litter, T10- Abamectina + poultry litter.

Al-Hazmi et al. (2019) also analyzed the effect of humic acid associated with *T. harzianum* and *P. lilacinum* on reproduction and mortality of J2, and found that when the interaction between humic acid + *T. harzianum* and humic acid + *P. lilacinum* is made, hatching inhibition may occur in 80 and 85%, respectively. Similarly, the population of J2 was suppressed in 74.6 and 78.1%. In both tests, the percentages were higher when there was a longer time of direct exposure of the nematodes to the organic compound and to the biological agents. Lima et al. (2011) found the efficiency of poultry litter on females of *H. glycines* and attributed this control to the chemical substances released during the decomposition process of the organic compost, corroborating the results found in this study.

In protected environment conditions, Dias-Arieira et al. (2018) observed the effect of *T. harzianum* and *P. lilacinum* in the reduction of populations of *P. brachyurus* in soybean, where these fungi were potentiated when used together with an organomineral fertilizer. In the same study, the authors saw that the use of *P. lilacinum + T. harzianum* can reduce the number of *P. brachyurus* per 10 g of root by up to 61.2% in soy at 40 DAS and 47.2% at 60 DAS, under field conditions.

Cerqueira et al. (2015) researching the effects of *B. subtillis* microbiolization in common bean, found an increase in dry and fresh mass of the aerial part and fresh mass of root. Machado and Costa (2017) working with biocontrol of *P. brachyurus* in soybeans, observed in greenhouse conditions that *B. subtilis* provided efficiency above 70% in the control

of *P. brachyurus*, when compared to the controls. Similar to previous research results, Oliveira et al. (2017) observed in bean plants at 30 DAS that treatment with *B. subtilis* via seed and spraying was equivalent to treatment with the chemical nematicide carbofuran.

Bacteria of the genus *Bacillus* sp. has the ability to colonize the rhizosphere of cultivated plants and produce antibiotic compounds (enzymes and toxins), forming a "protective film" on the roots, which interferes with plant and host recognition by nematode juveniles, reducing root penetration. In addition to causing disorientation in nematodes, bacteria of this genus, specifically *B. subtilis* and *B. amyloliquefaciens*, can induce systemic resistance in plants against phytopathogens and promote plant development through the release of volatile organic compounds (RYU et al., 2004; FARAG et al., 2013), thus explaining the better efficacy of bacteria when compared to fungi, in the control of *P. brachyurus*.

In relation to Abamectin + poultry litter, in addition to having efficiency compromised in the first days after sowing this experiment, the residual effect of the chemical nematicide is limited to the initial phase of the crop, allowing nematode population growth after this period. Similar to these results, Vitti (2009) did not observe the efficiency of abamectin on *H. glycines* at 60 days after sowing, only in the initial periods of development of soybean plants under field conditions.

The fungus *P. chlamydosporia*, in addition to affecting the reproduction of nematodes, has the ability to persist in the soil in adverse conditions and

also to perform the solubilization of phosphorus in the soil, which promotes better development of the root system. These benefits can be correlated with the control efficiency exerted by the fungus on populations of *P. brachurus* in corn. Nunes et al. (2010), evaluating the efficacy of the fungus *P. chlamydosporia* in the control of *M. incognita* in soybeans, obtained effective control when the fungus was used via seed treatment, and application in post-emergence of the crop. In parallel to this result, Nasu (2013) found that the use of *P. chlamydosporia* via seed treatment reduced population levels of *M. incognita* in soybeans and cotton in sandy and clayey soil, being the most efficient fungus in soil with greater porosity.

There are several factors that can influence the productivity of soybean plants in areas infested with nematodes, such as lack or excess of rain, soil fertility, population density, among others. According to Zavala-Gonzalez et al. (2015) and Monteiro (2013), *P. chlamydosporia* has the ability to stimulate plants to produce hormones important for plant development, as well as solubilizing phosphorus in the soil. Such factors, when provided in the initial development of plants, are fundamental to the yield of the crop.

In addition to the benefits promoted by *P. chlamydosporia*, the addition of poultry litter to the soil increases the availability of nutrients such as nitrogen, phosphorus and potassium for the cultivation of corn. Guerra et al. (2017) when developing a study with organic fertilization in the corn crop, found that plants that received 2 t ha^{-1} of poultry litter, expressed higher yield in relation to those that were not treated with organic compost. In this way, it is believed that the short period of time between the application of the soil poultry litter without mechanical incorporation and the sowing of soybeans, may have caused injuries to the roots due to the decomposition process of the organic material, causing a decline in productivity. In composting processes, carbon dioxide and water vapor are generated during the decomposition of organic substrates. In this process, the high microbiological activity reaches high intensity, causing an increase in temperature that can reach up to 65°C (PEREIRA NETO, 1987; KIEHL, 1998).

CONCLUSION

It was concluded that the use of *P. lilacinum* + *T. harzianum* and *B. subtilis* + *B. licheniform is* associated with the organic compost litter of chicken which promotes an increase in fresh root mass and decreases the number of nematodes in soybean and safrinha corn. The interaction of the fungus *P. chlamydosporia* with the organic compost promoted an increase in productivity. However, soybean sowing should be avoided soon after application

(without mechanical incorporation) of poultry litter.

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