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Bionematicides in sugarcane planting

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ABSTRACT

Biological nematicides have become the predominant treatment of sugarcane fields infested by nematodes, although there are few studies evaluating the effects of these products on this crop. In this context, the objective of this work was to evaluate the effect of *Bacillus subtilis* + *B. licheniformis* (®Quartz) and *Pochonia chlamydoporia* (®Rizotec) on nematode control and on sugarcane yield, comparing with a chemical nematicide, when applied on furrow. Eight experiments were carried on in São Paulo State infested areas, in which four treatments [check - no nematicide; carbosulfan 700EC 4 L ha^{-1} - standard treatment; *Bacillus subtilis* + *Bacillus licheniformis* (®Quartzo) 0.16 kg ha^{-1} and *P. chlamydoporia* (®Rizotec) 1 kg ha^{-1})] were applied on furrow. Carbosulfan was the most efficient treatment in *Pratylenchus* spp. control, reducing populations at least until four months after planting and contributing to average increases of 11% in yield. *P. chlamydosporia* reduced populations of *Pratylenchus* spp. four months after planting and promoted a productivity increase of 6% in relation to the control. The treatment with *B. subtilis* + *B. licheniformis* was less effective in nematodes control than the other treatments, and the plots treated

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with this biological product produced 5 % more than check.

Key words: *Bacillus subtilis, Bacillus licheniformis, Meloidogyne, Pratylenchus, Pochonia chlamidosporia.*

INTRODUCTION

Plant-parasitic nematodes are one of the important biotic constraints in sugarcane production in Brazil, and, since it is nearly impossible to eradicate nematodes present in a field, the best way to handle the infested area is integrating various control measures, aiming to reduce these parasites population or to improve plant development conditions (Dinardo-Miranda, 2018). For many years, chemical nematicides were the most common method in sugarcane. However, from the 2020s onwards, biological nematicides have become predominant in the treatment of sugarcane fields infested by nematodes, although there are few studies conducted with these products in the field conditions.

One of these studies was conducted by Mazzuchelli et al. (2020), who applied *Bacillus subtilis* on furrow and observed that the rhizobacteria provided effective control of *Meloidogyne* sp. and *Pratylenchus* spp. and, in consequence, there was a yield increase in treated plots. Another example includes five experiments carried on by Dinardo-Miranda et al. (2022), who worked with a mix of *Bacillus subtilis* + *B. licheniformis* applied on furrow, and observed that the mix of *Bacillus* was less efficient to reduce nematode populations than the chemical nematicide carbosulfan, promoting a smaller increase in productivity in relation to the check than the chemical product.

Although rhizobacteria have stood out as biological nematicides in sugarcane, the nematode antagonistic fungi *Pochonia chlamydosporia* is also attracting greater attention as a potential biocontrol agent. In addition to fighting phytopathogenic nematodes (Zinger et al., 2021; Alves et al., 2022), it has also been reported as growth promoting fungus of some crops (Monteiro et al., 2020). Involving sugarcane, Sankaranarayanan; Hari (2013, 2021) conducted

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experiments under potted condition and observed that *P. chlamydosporia* promoted 36% galling and 30 % nematode population reduction in experiment conducted with *M. javanica* (Sankaranarayanan; Hari, 2013) and 46% reduction in the nematode population in the roots in experiment involving *Pratylenchus zeae* (Sankaranarayanan; Hari, 2021).

Due to the few studies in sugarcane fields naturally infested by nematodes, specially involving *P. chlamydiosporia*, the objective of this work was to evaluate the effect of *Bacillus subtilis* + *B. licheniformis* (®Quartzo) and *P. chlamydosporia* (®Rizotec) on nematode control and on sugarcane yield, when applied on furrow in field conditions, compared to chemical nematicide carbosulfan (®Marshal Star).

MATERIAL AND METHODS

This study consisted of eight experiments conducted in naturally nematodes infested areas in São Paulo State (Santa Cruz das Palmeiras - experiment 1; Serrana - experiments 2, 5 and 8; Olimpia - experiment 3; Araras - experiment 4; Lençóis Paulista - experiment 6; and Tanabi - experiment 7). The planting date and cultivar used in each experiment were: 01 December 2016 and CTC11 in experiment 1; 10 January 2017 and CTC4 in experiment 2; 21 February 2017 and RB867515 in experiment 3; 10 March 2017 and SP80-1816 in experiment 4; 18 March 2017 and CTC4 in experiment 5; 30 May 2017 and RB975357 in experiment 6; 25 March 2019 and CTC9003 in experiment 7; and 26 March 2019 and CTC002627 in experiment 8. All experiments were conducted in a randomized block design, with five (experiments 1, 5, 6, 7), six (experiments 2, 3, 4) or 12 (experiment 8) replications. The plots were represented by 6-furrows with 10 m, spaced apart by 1.5 m.

The studied treatments were: a) check (no nematicide); b) carbosulfan (®Marshal Star 700EC) 4,5 L ha^{-1} (standard treatment); c) *Bacillus subtilis* + *Bacillus licheniformis* (®Quartzo) 0,20 kg ha^{-1} and d) *Pochonia chlamydosporia* (®Rizotec) 1 kg ha^{-1}. All nematicide treatments were applied in furrow planting with a CO_2 pressurized backpack sprayer, after which the furrows

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were immediately covered with soil.

To evaluate the effect of treatments on nematode populations, soil and plant roots samples were collected at two, four and ten months after planting, except in experiment 7, in which the samplings were done two and four months. In all experiments, in each plot and sampling, plant roots and soil were collected from the first and the sixth furrow, and the nematodes extracted by the combination of sieving and centrifugation with sucrose solution (Coolen; D'Herde, 1972; Jenkins, 1964). The productivity of each plot was obtained around 14 months after planting, by the biometric method (Landell et al., 1999), considering the stalks from second to fifth furrows.

For statistical analysis, the population data were transformed by the square root of (x + 1). For each experiment, the data were subjected to analysis of variance, and the means were compared by t test at 5 % significance. After the analysis of each experiment, the data were analyzed in conjunction. Since the number of replications was not the equal for all experiments, for these analyses, each experiment was considered as one replication, using the mean data for each parameter and treatment, as suggested by Gomes (1982). For statistical analysis, Agroestat software program was used (Barbosa; Maldonado, 2011).

RESULTS AND DISCUSSION

P. zeae and *Meloidogyne javanica* were founded in all experimental fields, while *Pratylenchus brachyurus* was recorded in experiment 2 and 8, and *Meloidogyne incognita* in experiment 8 (Tables 1 to 8).

In experiments 1, 2, 4 and 6, the nematicides did not significantly reduced the nematode population, comparing with check treatment, in all sampling carried on (Tables 1, 2, 4 and 6). Despite that, in experiment 1, plots treated with nematicides produced about 10% more than the check, a statistically significant value (Table 1). The increase in productivity of the plots treated with carbosulfan may be the result of a nematode population reduction, in a period prior

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to the two months, when the first sampling was made. It is known that the hotter and rainier the epoch of planting, the shorter is the period in which chemical nematicides remain effective, because they can be leached and metabolized by plants more quickly than in plantations made in drier epoch (Dinardo-Miranda, 2018; Dinardo-Miranda et al., 2022). So, since the experiment 1 was planted in December, it was subjected to a greater rainfall volume in the first two months after planting (347.8 mm), than the other experiments (251.9, 146.8, 209.0, 77.8, 0, 26.4 and 34.4 mm in experiment 2, 3, 4, 5, 6, 7 and 8, respectively), which would justify that, at two months, when the first sampling was carried out, there was not a significant reduction in nematode populations in plots treated by carbosulfan. By the other hands, the productivity in plots treated with biological nematicides also was higher than the check in experiment 1, which can be attributed to effects of microorganisms on plant growth. It is well known that *P. chlamydosporia*, *B. subtilis* and *B. licheniformis* promotes plant growth and increases crops productivity (Sukkasem et al., 2018; Monteiro et al., 2020; Mahapatra et al., 2022).

The productivity data from experiment 2 were not obtained (Table 2).

In experiments 4 and 6, the lack of significant increase in productivity due to nematicides application is explained by the lack of effectiveness of those products on nematode control. (Tables 4 and 6).

In experiment 3, nematicides treatments did not significantly reduced *M. javanica* population, both in roots and in soil, comparing with check treatment, in all sampling carried on, but carbosulfan and *B. subtilis* + *B. licheniformis* reduced *P. zeae* population on roots at least two months after planting, while *P. chlamydosporia* reduced *P. zeae* populations on roots at least four months after planting. As a result of the better control of *P. zeae*, in the first months of the plants development, the highest productivity was observed in the treatment with P. *chlamydosporia*, which differed significantly from that observed in the check plots. Plots treated with P. *chlamydosporia* produced 13 % more than the check (Table 3).

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In experiments 5 and 7, the carbosulfan effect on the reduction of *P. zeae* population in plant roots was observed at two and four months after planting, while the effect of *B. subtilis* + *B. licheniformis* treatment on the reduction of *P. zeae* population in plant roots was observed just in experiment 7, at four months after planting. *P. chlamydosporia* had no significant effect on *P. zeae* population in plant roots. No nematicide interfered with the *M. javanica* populations in the roots in both experiments (Tables 5 and 7). In both experiments, the productivity of plots treated with carbosulfan was significantly higher than that of the check plots, in response to the reduction in the population of *P. zeae* in the first months of plant development. Since the treatments with *B. subtilis* + *B. licheniformis* and *P. chlamydosporia* did not significantly reduced nematode population in plants roots in experiment 5, the productivity observed in these treatments were like the check, although they did not differ of the treatment with carbosulfan (Table 5). In experiment 7, plots treated with *P. chlamydosporia* produced more than the control, although this treatment did not significantly reduce nematode population (Table 7). These data suggest that, also in the experiment 7, the fungus may have acted as a growth promoter, as described by several researchers as Farias et al. (2018) and Monteiro et al. (2020).

In experiment 8, just carbosulfan significantly reduced *P. zeae* + *P. brachyurus* population in plants roots, in all samplings. Because of this, the productivity of plots treated with carbosulfan was higher than the others (Table 8).

The treatments performance can be better evaluated by analyzing the nematode population data from eight experiments and yield data from seven experiments (Table 9). No nematicide significantly reduced the population of *Meloidogyne* spp. in plants roots, in all samplings carried out, but plots treated with biological nematicides showed lower populations of *Meloidogyn*e spp. in the soil ten months after planting, compared to check- and carbosulfan-treated plots. In relation to *Pratylenchus* spp. population, carbosulfan was the most efficient treatment, reducing *P. zeae* or *P. zeae* + *P. brachyurus* populations in plants roots at least until

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four months after planting. *P. chlamydosporia* significantly reduced *Pratylenchus* spp. population at four months after planting. In this occasion, *Pratylenchus* spp. population in roots differed significantly that observed on check plots and did not differ from the observed in carbosulfan treatment. The treatment with *B. subtilis* + *B. licheniformis* was less effective, since the *Pratylenchus* spp. population in roots in this treatment did not differ significantly that observed on check plots and did not differ from the observed in carbosulfan treatment (Table 9).

Plots treated with nematicides produced significantly more than check plots. Since carbosulfan was more efficient in *Pratylenchus* spp. control, at least until four months after planting, the higher yield was observed in that treatment, followed by treatments with *P. chlamydosporia* and *B. subtilis* + *B. licheniformis.* Plots treated with carbosulfan produced on average 10 % more than check plots, while plots treated with *P. chlamydosporia* and *B. subtilis* + *B. licheniformis* produced 6 and 5 % more than check, respectively (Table 9).

According to several researchers, bacteria belonging to genus *Bacillus* may present different action mechanisms on plant-parasitic nematodes, namely, the production of toxic metabolites, the interference in host recognition, the competition for nutrients and the resistance induction in plants (Sukkasem et al., 2018; Mahapatra et al., 2022). *P. chlamydosporia* reduces nematode populations because it infects nematode eggs and J2-stage juveniles by means of its ability to produce secondary metabolites such as aurovertins and pochonins, among others (Zhou et al., 2010) and acts to induce resistance to the nematodes (Monteiro et al., 2020). For both biological nematicides, all these mechanisms contribute to reduce the number of nematodes inside the roots, as registered in the present work, especially in experiments 3 and 7, and on average of eight experiments.

The results of these experiments are partially in agreement with those from Cardoso; Araújo (2011) and Morgado et al. (2015), who reported that the application of *B. subtilis* in the

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soil caused the reduction of *Meloidogyne s*pp. and *P. zeae* reproduction factor, while reduction of *Meloidogyne s*pp. population was not observed here. However, those researchers conducted the work in greenhouse, not in infested field.

The results of present study also agree with those obtained by Mazzuchelli et al. (2020) just partially. Although those authors had worked with *B. subtilis*, they reported that the biological product was more efficient than the chemical nematicide on nematode control, reducing nematode population until during the ratoon. In the present work, chemical nematicide was more efficient than biological product and, in both cases, around ten months after planting, nematode population was high in all plots, including in the check ones. Moreover, in the present study, the nematode population reduction was followed by increased productivity.

As in the present study, Dinardo-Miranda et al. (2022) also observed that carbosulfan was more efficient than *B. subtilis* + *B. licheniformis* to reduce nematode populations, at least until four months after sugarcane planting, increasing sugarcane yield in 11%. *B. subtilis* + *B. licheniformis* promoted 5% increase in productivity, values like those observed in the present study. Those authors, however, reported a certain effectiveness of the biological nematicide in the control of *M. javanica*, which was not verified in this study.

In relation to *P. chlamydosporia*, the results of present study agree with those obtained by Sankaranarayanan; Hari (2021), that registered reduction in *P. zeae* population in sugarcane roots conducted in pots treated with the fungus, comparing with no treated pots, but they are in disagreement with those obtained by Sankaranarayanan; Hari (2013), that also registered reduction in *M. javanica* population in sugarcane roots conducted in pots treated with the fungus, comparing with no treated pots.

CONCLUSION

P. chlamydosporia is more efficient than *B. subtilis* + *B. licheniformis* in reducing the

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Pratylenchus spp. populations in sugarcane roots, but it is less efficient than carbosulfan. On average, *P. chlamydosporia* and *B. subtilis* + *B. licheniformis* increase sugarcane yield in 6 and 5 %, respectively, while carbosulfan increases in 10 %.

AUTHORSHIP CONTRIBUTION (CONTRIBUIÇÃO DE AUTORIA)

Leila Luci Dinardo-Miranda
Conceptualization (Lead); Data curation (Lead); Formal analysis (Lead); Investigation (Equal); Methodology (Equal); Project administration (Equal); Writing - original draft (Equal); Writing - review & editing (Equal)

Isabella Dinardo Miranda
Conceptualization (Supporting); Formal analysis (Supporting); Investigation (Supporting); Writing - original draft (Equal); Writing - review & editing (Equal)

Higor Domingos Silvério da Silva
Data curation (Equal); Investigation (Equal); Validation (Equal)

Juliano Vilela Fracasso
Data curation (Equal); Investigation (Equal); Methodology (Equal); Validation (Equal)

AVAILABILITY OF DATA AND MATERIAL (declaração de disponibilidade de dados de pesquisa)

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

FUNDING

Not applicable.

CONFLICTS OF INTEREST

All authors declare that they have no conflict of interest.

ETHICAL APPROVAL

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Not applicable.

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Table 1. Population *of Meloidogyne javanica* second-stage juvenile (Mj) and of *Pratylenchus zeae* adult and juvenile (Pz) in roots (50 g) and soil (1 L), at two, four and ten months after planting, and stalks yield at the harvest (SYH, T per ha), according to nematicides treatments. Experiment 1.

Treatment	2 months				4 months				10 months				SYH
	roots		soil		roots		soil		roots		soil		
	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	
Check	0 a	2699 b	0 a	624 a	199 a	9965 a	240 a	1008 a	121 a	8906 a	36 a	564 a	101 b
Carbosulfan	0 a	3340 ab	0 a	552 a	90 a	8500 a	0 a	1104 a	33 a	12328 a	12 a	624 a	112 a
*Bs + Bl**	0 a	10354 a	0 a	300 a	0 a	8980 a	0 a	1238 a	0 a	13276 a	0 a	660 a	110 a
*Pc***	0 a	7093 ab	0 a	300 a	120 a	6556 a	48 a	950 a	202 a	12549 a	0 a	408 a	113 a

**Bacillus subtilis + B. licheniformis*

** *Pochonia chlamydosporia*

Means within the same column followed by the same letter are not significantly different (t test, $p \leq 0.05$).

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Table 2. Population *of Meloidogyne javanica* second-stage juvenile (Mj) and of *Pratylenchus zeae* + *P. brachyurus* adult and juvenile (Pspp) in roots (50 g) and soil (1 L), at two, four and ten months after planting. Experiment 2.

Treatment	2 months				4 months				10 months			
	roots		soil		roots		soil		roots		soil	
	Mj	Pspp	Mj	Pspp	Mj	Pspp	Mj	Pspp	Mj	Pspp	Mj	Pspp
Check	0 a	6678 a	0 a	1270 a	25 a	11200 a	0 a	630 a	125 a	10150 a	40 a	720 a
Carbosulfan	0 a	6630 a	0 a	1050 a	0 a	9458 a	0 a	600 a	0 a	11267 a	0 a	460 a
*Bs + Bl**	0 a	6694 a	0 a	1300 a	8 a	9617 a	10 a	620 a	0 a	12608 a	0 a	870 a
*Pc***	0 a	5870 a	0 a	700 a	0 a	9039 a	0 a	600 a	0 a	9967 a	0 a	880 a

**Bacillus subtilis* + *B. licheniformis*

** *Pochonia chlamydosporia*

Means within the same column followed by the same letter are not significantly different (t test, $p \leq 0.05$).

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Table 3. Population *of Meloidogyne javanica* second-stage juvenile (Mj) and of *Pratylenchus zeae* adult and juvenile (Pz) in roots (50 g) and soil (1 L), at two, four and ten months after planting, and stalks yield at the harvest (SYH, T per ha), according to nematicides treatments. Experiment 3.

Treatment	2 months				4 months				10 months				SYH
	roots		soil		roots		soil		roots		soil		
	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	
Check	96 ab	12875 a	90 ab	1040 a	2500 a	12417 a	160 b	990 a	25 b	1650 ab	0 a	300 ab	115 b
Carbosulfan	25 ab	4746 b	50 b	1270 a	1992 a	8800 ab	280 b	840 a	142 ab	3117 a	250 a	560 a	122 ab
*Bs + Bl**	0 b	7652 b	10 b	1920 a	4633 a	10083 ab	160 b	710 a	117 ab	883 c	0 a	370 ab	120 ab
*Pc***	325 a	7104 b	480 a	2150 a	4489 a	5553 b	1110 a	910 a	400 a	1383 bc	30 a	160 b	130 a

**Bacillus subtilis + B. licheniformis*

** *Pochonia chlamydosporia*

Means within the same column followed by the same letter are not significantly different (t test, $p \leq 0.05$).

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Table 4. Population *of Meloidogyne javanica* second-stage juvenile (Mj) and of *Pratylenchus zeae* adult and juvenile (Pz) in roots (50 g) and soil (1 L), at two, four and ten months after planting, and stalks yield at the harvest (SYH, T per ha), according to nematicides treatments. Experiment 4.

Treatment	2 months				4 months				10 months				SYH
	roots		soil		roots		soil		roots		soil		
	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	
Check	0 a	3707 ab	0 a	210 a	17 a	1300 a	0 a	110 a	0 a	1875 a	0 a	290 a	127 a
Carbosulfan	25 a	2089 b	0 a	250 a	8 a	975 a	0 a	180 a	8 a	1717 a	0 a	170 a	136 a
*Bs + Bl**	0 a	3850 ab	0 a	250 a	0 a	942 a	0 a	150 a	0 a	1883 a	0 a	140 a	132 a
*Pc***	0 a	5049 a	0 a	190 a	0 a	1642 a	0 a	150 a	0 a	2250 a	0 a	150 a	134 a

**Bacillus subtilis + B. licheniformis*

** *Pochonia chlamydosporia*

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Table 5. Population *of Meloidogyne javanica* second-stage juvenile (Mj) and of *Pratylenchus zeae* adult and juvenile (Pz) in roots (50 g) and soil (1 L), at two, four and ten months after planting, and stalks yield at the harvest (SYH, T per ha), according to nematicides treatments. Experiment 5.

Treatment	2 months				4 months				10 months				SYH
	roots		soil		roots		soil		roots		soil		
	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	
Check	71 a	7168 a	12 a	204 a	417 a	8105 ab	0 b	96 ab	220 a	2040 a	840 a	504 a	88 b
Carbosulfan	0 a	2856 b	0 a	60 b	290 a	3990 b	0 b	24 b	980 a	2500 a	780 ab	180 a	98 a
*Bs + Bl**	0 a	6559 a	0 a	84 b	304 a	11524 a	0 b	192 a	500 a	1970 a	48 b	528 a	92 ab
*Pc***	0 a	6359 a	84 a	120 ab	42 a	7950 ab	24 a	36 b	230 a	3770 a	36 b	336 a	89 ab

**Bacillus subtilis + B. licheniformis*

** *Pochonia chlamydosporia*

Means within the same column followed by the same letter are not significantly different (t test, $p \leq 0.05$).

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Table 6. Population *of Meloidogyne javanica* second-stage juvenile (Mj) and of *Pratylenchus zeae* adult and juvenile (Pz) in roots (50 g) and soil (1 L), at two, four and ten months after planting, and stalks yield at the harvest (SYH, T per ha), according to nematicides treatments. Experiment 6.

Treatment	2 months				4 months				10 months				SYH
	roots		soil		roots		soil		roots		soil		
	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	
Check	0 a	145 a	0 a	12 a	80 a	3760 a	60 a	48 a	592 a	1250 a	90 a	204 a	72 a
Carbosulfan	0 a	121 a	12 a	24 a	5420 a	1270 a	528 a	96 a	190 a	590 a	48 a	96 a	79 a
*Bs + Bl**	30 a	114 a	0 a	0 a	1280 a	3820 a	180 a	108 a	340 a	1180 a	72 a	192 a	78 a
*Pc***	30 a	90 a	0 a	12 a	7670 a	2600 a	1608 a	36 a	470 a	750 a	144 a	168 a	79 a

**Bacillus subtilis + B. licheniformis*

** *Pochonia chlamydosporia*

Means within the same column followed by the same letter are not significantly different (t test, $p \leq 0.05$).

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Table 7. Population *of Meloidogyne javanica* second-stage juvenile (Mj) and of *Pratylenchus zeae* adult and juvenile (Pz) in roots (50 g) and soil (1 L), at two and four months after planting, and stalks yield at the harvest (SYH, T per ha), according to nematicides treatments. Experiment 7.

Treatment	2 months				4 months				SYH
	roots		soil		roots		soil		
	Mj	Pz	Mj	Pz	Mj	Pz	Mj	Pz	
Check	90 a	6370 a	36 b	540 a	280 a	6324 a	0 b	76 a	135 c
Carbosulfan	70 a	1670 b	204 a	180 ab	0 a	2257 b	216 a	216 a	158 a
*Bs + Bl**	60 a	3820 ab	24 b	120 b	360 a	3289 b	144 ab	144 a	138 bc
*Pc***	50 a	3504 ab	0 b	204 ab	280 a	3550 b	48 ab	48 ab	150 ab

**Bacillus subtilis + B. licheniformis*

*** Pochonia chlamydosporia*

Means within the same column followed by the same letter are not significantly different (t test, $p \leq 0.05$).

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Table 8. Population *of Meloidogyne javanica* + *M. inconita* second-stage juvenile (Mspp) and of *Pratylenchus zeae* + *P. brachyurus* adult and juvenile (Pspp) in roots (50 g) and soil (1 L), at two, four and ten months after planting, and stalks yield at the harvest (SYH, T per ha), according to nematicides treatments. Experiment 8.

Treatment	2 months				4 months				10 months				SYH
	roots		soil		roots		soil		roots		soil		
	Mspp	Pspp	Mspp	Pspp	Mspp	Pspp	Mspp	Pspp	Mspp	Pspp	Mspp	Pspp	
Check	4 a	4001 a	15 a	210 a	334 b	4677 a	10 b	45 a	570 a	4991 a	45 b	75 ab	98 b
Carbosulfan	126 a	1085 b	10 a	30 b	756 ab	458 b	50 ab	45 a	2147 a	1774 b	185 a	30 b	106 a
*Bs + Bl**	47 a	5573 a	10 a	60 b	1624 ab	4141 a	130 a	70 a	890 a	3971a	30 b	80 ab	99 b
*Pc***	63 a	4294 a	20 a	105 ab	2399 a	3003 a	55 ab	60 a	1784 a	4574 a	50 b	150 a	98 b

**Bacillus subtilis* + *B. licheniformis*

** *Pochonia chlamydosporia*

Means within the same column followed by the same letter are not significantly different (t test, $p \leq 0.05$). Table 9. Population *of Meloidogyne* spp. second-stage juvenile (Mspp) and of *Pratylenchus* spp. adult and juvenile (Pspp) in roots (50 g) and soil (1 L),

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at two, four and ten months after planting, and stalks yield at the harvest (SYH, T per ha), according to nematicides treatments. Mean of eight experiments.

Treatment	2 months				4 months				10 months				SYH
	roots		soil		roots		soil		roots		soil		
	Mspp	Pspp	Mspp	Pspp	Mspp	Pspp	Mspp	Pspp	Mspp	Pspp	Mspp	Pspp	
Check	33 a	5455 a	19 a	514 a	481 a	7219 a	32 b	375 a	236 a	4408 a	159 ab	379 a	105 c
Carbosulfan	31 a	2817 b	35 a	427 a	1070 a	4464 c	134 ab	388 a	500 a	4756 a	182 a	303 a	116 a
*Bs + Bl**	17 a	5570 a	6 a	504 a	1026 a	6549 ab	78 ab	406 a	263 a	5110 a	21 b	405 a	110 b
*Pc***	59 a	4920 a	73 a	473 a	1875 a	4987 bc	362 a	371 a	441 a	5035 a	37 b	365 a	113 ab

**Bacillus subtilis + B. licheniformis*

*** Pochonia chlamydosporia*

Means within the same column followed by the same letter are not significantly different (t test, $p \leq 0.05$).

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