Research Article

Response of plants used in cover crop mix to *Meloidogyne enterolobii*, *Meloidogyne incognita* and *Pratylenchus brachyurus*[1]

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ABSTRACT

Cover crop species have been used in mixes in order to improve soil conditions; however, it is important to evaluate the relationship of the employed cultivars with phytonematodes to identify those that do not multiply the pathogens in the cultivated area. This study aimed to assess the response of 11 plant species used in cover crop mix to *Meloidogyne enterolobii*, *M. incognita* and *Pratylenchus brachyurus*. Six experiments were conducted in a greenhouse, using a completely randomized design, with five replications. BMX Potência RR soybean and Santa Clara tomato were used as controls. In at least one of the experiments, IPR 91 Baili buckwheat was susceptible (reproduction factor - RF $\geq$ 1) to *M. enterolobii*, *M. incognita* and *P. brachyurus*. Common white lupin, URS Altiva white oat, Iapar 61 (Ibiporã) black oat and Embrapa 139 (Neblina) black oat were susceptible to *M. enterolobii* and *M. incognita* and resistant (RF < 1) and/or immune (RF = 0) to *P. brachyurus*. IPR 89 rye and IPR 116 radish were found susceptible to *M. incognita* and *P. brachyurus* and resistant to *M. enterolobii*. BRS 1501 millet and Embrapa 29 (Garoa) black oat were susceptible to *M. incognita* and resistant/immune to *M. enterolobii* and *P. brachyurus*. *Brachiaria ruziziensis* was considered resistant to *M. enterolobii* and *M. incognita* and susceptible to *P. brachyurus*. URS Corona white oat was the only cover crop considered to be resistant and/or immune to all the nematode species evaluated.

KEYWORDS: Root-knot nematode, lesion nematode, green manure, crop rotation.

RESUMO

Reação de espécies vegetais utilizadas em mix de plantas de cobertura a *Meloidogyne enterolobii*, *Meloidogyne incognita* e *Pratylenchus brachyurus*

Espécies de plantas de cobertura vêm sendo utilizadas em mixes, visando melhorar as condições do solo; porém, é importante avaliar a relação das cultivares utilizadas com fitonematoides, a fim de identificar aquelas que não multipliquem os patógenos na área cultivada. Objetivou-se avaliar a reação de 11 espécies vegetais utilizadas em mix de plantas de cobertura a *Meloidogyne enterolobii*, *M. incognita* e *Pratylenchus brachyurus*. Foram conduzidos 6 experimentos em casa-de-vegetação, em delineamento inteiramente casualizado, com 5 repetições, utilizando-se a soja BMX Potência RR e o tomate Santa Clara como testemunhas. Em pelo menos um dos experimentos, o trigo mourisco IPR 91 Baili foi suscetível (fator de reprodução - FR $\geq$ 1) a *M. enterolobii*, *M. incognita* e *P. brachyurus*. O tremoço-branco cv. comum, aveia branca URS Altiva, aveia preta Iapar 61 (Ibiporã) e aveia preta Embrapa 139 (Neblina) foram suscetíveis a *M. enterolobii* e *M. incognita* e resistentes (FR < 1) e/ou imunes (FR = 0) a *P. brachyurus*. O centeio IPR 89 e o nabo forrageiro IPR 116 foram suscetíveis a *M. incognita* e *P. brachyurus* e resistentes a *M. enterolobii*. O milheto BRS 1501 e a aveia preta Embrapa 29 (Garoa) foram suscetíveis a *M. incognita* e resistentes/imunes a *M. enterolobii* e *P. brachyurus*. A *Brachiaria ruziziensis* foi considerada resistente a *M. enterolobii* e *M. incognita* e suscetível a *P. brachyurus*. A aveia branca URS Corona foi a única planta considerada resistente e/ou imune para todas as espécies de nematoides avaliadas.

PALAVRAS-CHAVE: Nematoide-de-galhas, nematoide-das-lesões-radiculares, adubação verde, rotação de culturas.

INTRODUCTION

Nematodes of the *Meloidogyne* genus, commonly known as root-knot nematodes, are major pests of economically important crops worldwide (Rusinque et al. 2022). In Brazil, two *Meloidogyne* species deserve attention for their extensive geographic distribution and damage potential, namely *Meloidogyne javanica* (Treub 1885) Chitwood (1949) and *Meloidogyne incognita* (Kofoid & White 1919) Chitwood (1949) (Henning et al. 2014). Another root-knot nematode species that has gained prominence as a crop pest in recent years is *Meloidogyne enterolobii* Yang & Eisenback (1983) (Castro 2019).

[1] Received: Apr. 05, 2023. Accepted: June 26, 2023. Published: Aug. 31, 2023. DOI: 10.1590/1983-40632023v5375822.
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Pratylenchus brachyurus (Godfrey 1929) Filipjev & Stekhoven (1941), known as lesion nematode, also merits attention because of its polyphagous nature and wide geographical distribution (Cruz et al. 2020).

Crop rotation with antagonist or non-host plants is a key practice for reducing plant-parasitic nematodes in the field. Black oat (*Avena strigosa* Schreb.) and white oat (*Avena sativa* L.) have several advantages as rotation crops, such as fast growth, high biomass production, large root growth (Silva et al. 2021) and potential to control *Meloidogyne* spp. (Riede et al. 2015, Marini et al. 2016) and *P. brachyurus* (Gabriel et al. 2018), depending on the cultivar used (Machado et al. 2015). Pearl millet (*Pennisetum glaucum* L.), rye (*Secale cereale* L.) and signalgrass (*Brachiaria* spp.) are grasses with high biomass production, constituting valuable additions to crop rotation systems. Furthermore, millet promotes nutrient accumulation and release and improves soil properties (Silva et al. 2021). Radish (*Raphanus sativus* L.), although a potential species for crop rotation, was found to be susceptible to *M. javanica* (Rosa et al. 2013), but resistant to *P. brachyurus* (Chiamolera et al. 2012). Buckwheat (*Fagopyrum esculentum* Moench) and white lupin (*Lupinus albus* L.) are gaining popularity in rotation systems, but there is limited information on the effects of these species on nematode management.

The aforementioned species are used in cover crop seed mixes to improve soil physical, chemical and biological properties. Cover crop mixes have numerous advantages over monocultures (Ziech et al. 2015). It is recommended to use species belonging to the families Brassicaceae, Fabaceae, Poaceae and Polygonaceae, as their diverse characteristics complement one another, resulting in benefits for the system (Silva et al. 2021). Cover crop combinations should be selected according to the purposes of crop rotation and the ability of plants to adapt to local conditions. This approach aims to maximize the benefits to the soil microbial community, soil parameters and yield of successive crops (Silva et al. 2021).

It is understood that the relationship of cover crop cultivars with plant-parasitic nematodes is a crucial factor influencing the success of nematode management and the performance of rotation systems. Specifically in the case of cover crop mixes, it is of paramount importance to choose cultivars that do not increase pathogen populations in the field. Thus, this study aimed to investigate the response of plants used in cover crop mix to *M. enterolobii*, *M. incognita* and *P. brachyurus*.

MATERIAL AND METHODS

Six experiments were conducted in a greenhouse (SAD69 22º50′48″S, 48º26′06″W and 817.74 m above the sea level) at the Universidade Estadual Paulista, in Botucatu, São Paulo state, Brazil, from 2020 to 2021.

The experimental design was completely randomized, with five replications, and the treatments included 11 plant species commonly found in cover crop seed mixes (Table 1) inoculated separately with *Meloidogyne enterolobii*, *M. incognita* and *Pratylenchus brachyurus*. Each experiment was conducted at two different times. For *M. enterolobii*, the first experiment (experiment A) was conducted from September to November 2020 (average temperature of 23.6 ºC) and the second (experiment B) from October to December 2020 (average temperature of 23.5 ºC). For *M. incognita*, the first experiment (experiment C) lasted from November 2020 to January 2021 (average temperature of 23.9 ºC) and the second (experiment D) from December 2020 to February 2021 (average temperature of 24.12 ºC). For *P. brachyurus*, the first experiment (experiment E) was conducted from March to June 2020 (average temperature of 20.9 ºC) and the second (experiment F) from September to December 2020 (average temperature of 23.7 ºC).

White oat, black oat, rye, ruzigrass and millet were sown at a density of 10 seeds pot^{-1}, whereas radish was sown at 5 seeds pot^{-1} and buckwheat and lupin at 2 seeds pot^{-1}. Each pot was treated as an experimental unit. At 10 days after germination, white oat, black oat, rye, ruzigrass and millet plants were thinned to 7 plants pot^{-1}, and the other species were thinned to 1 plant pot^{-1}. Nematode inoculation was performed on the following day.

The *M. enterolobii* and *M. incognita* inocula were obtained from pure populations maintained on Santa Clara tomato (*Lycopersicon esculentum* L.) and Santa Cruz okra (*Abelmoschus esculentus* Moench). The *P. brachyurus* inoculum was obtained from velvet bean (*Mucuna pruriens* L). Nematodes were extracted according to Bonetti & Ferraz (1981). *M. enterolobii* and *M. incognita* suspensions were adjusted to 2,000 eggs + eventual second-stage

Table 1. List of plant species used in the experiments.

Common name and cultivar	Scientific name	Family
BMX Potência RR soybean (control)	*Glycine max* (L.) Merril	Fabaceae
URS Altiva white oat	*Avena sativa* L.	Poaceae
Santa Clara tomato	*Solanum lycopersicum*	Solanaceae
URS Corona white oat	*Avena sativa* L.	Poaceae
IPR 89 rye	*Secale cereale* L.	Poaceae
IPR 116 radish	*Raphanus sativus* L.	Brassicaceae
Embrapa 29 (Garoa) black oat	*Avena strigosa* Schreb.	Poaceae
Embrapa 139 (Neblina) black oat	*Avena strigosa* Schreb.	Poaceae
Iapar 61 Ibiporã black oat	*Avena sativa* L.	Poaceae
White lupin	*Lupinus albus* L.	Fabaceae
BRS 1501 pearl millet	*Pennisetum glaucum* L.	Poaceae
IPR 91 Baili buckwheat	*Fagopyrum esculentum* Moench	Polygonaceae
Ruzigrass	*Brachiaria ruziziensis*	Poaceae

juveniles (J2) mL^{-1} in a Peters chamber under an optical microscope. The *P. brachyurus* suspension was adjusted to 1,000 individuals mL^{-1}.

The experimental units consisted of 500 cm^3 pots for experiments with *M. enterolobii* and *M. incognita* and 1,000 cm^3 pots for experiments with *P. brachyurus*. The substrate consisted of a mixture of sand and soil (2:1 ratio) previously autoclaved at 120 ºC, for 2 h. For inoculation, two holes of about 2 cm deep were made in the substrate, to which the nematode suspension was added. BMX Potência RR soybean was used as a control of inoculum viability in the experiments with *M. incognita* and *P. brachyurus*, and Santa Clara tomato was used as control in the experiments with *M. enterolobii*.

Plants inoculated with *M. enterolobii* or *M. incognita* were kept in the greenhouse for 60 days. For *P. brachyurus*, the experimental period was 80 days after inoculation. Plants were irrigated daily as needed. After this period, they were collected and their roots were separated from shoots. The roots were washed to eliminate the soil excess, placed on absorbent paper to remove water excess, and weighed on a semi-analytical scale to obtain the root fresh weight.

The roots were subjected to nematode extraction (Bonetti & Ferraz 1981). Subsequently, the number of nematodes (total number of nematodes = final population) was quantified in a Peters chamber under an optical microscope. The total number of nematodes was divided by the root fresh weight to estimate the number of nematodes per gram of root (population density). The reproduction factor (RF) was calculated by the equation RF = final population ÷ initial population, and the plants were classified as immune (RF = 0), resistant (RF < 1) or susceptible (RF ≥ 1) to nematodes (Oostenbrink 1966).

The experimental data were subjected to analysis of variance and the means compared by the Scott-Knott test at 5 % of probability using the Agrostat software (Barbosa & Maldonado Júnior 2015). When needed to fulfill normality assumptions, the data were transformed by $\sqrt{(x + 0.5)}$.

RESULTS AND DISCUSSION

In the experiment A (conducted from September to November 2020, with average temperature of 23.6 ºC), the *M. enterolobii* population density was higher for IPR 91 Baili buckwheat (1,646 nematodes) and Santa Clara tomato (control) (1,480 nematodes), followed by URS Altiva white oat (785 nematodes). For Embrapa 139 (Neblina) black oat, Embrapa 29 (Garoa) black oat, Iapar 61 Ibiporã black oat, white lupin, IPR 116 radish, IPR 89 rye, BRS 1501 millet and ruzigrass, the mean population density ranged from 7 to 473 nematodes g^{-1} of root (Table 2). Only the inoculum control (Santa Clara tomato) and Embrapa 139 (Neblina) black oat had RF ≥ 1 (Table 2). Almost all the other plant species were resistant (RF < 1), except for URS Corona white oat, which was immune (RF = 0).

In the experiment B (conducted from October to December 2020, with average temperature of 23.5 ºC), the highest population density was recorded for URS Altiva white oat (2,811 nematodes), followed by IPR 91 Baili buckwheat (2,479 nematodes) and

Table 2. Population density and reproduction factor (RF) of *Meloidogyne enterolobii* on cover crops at 60 days after inoculation, in two experiments.

Crop	Experiment A (Sep. to Nov. 2020)			Experiment B (Oct. to Dec. 2020)		
	Population density	RF	Plant response[1]	Population density	RF	Plant response[1]
White lupin	326 b*	0.4	R	819 b	1.6	S
IPR 91 Baili buckwheat	1,646 a	0.7	R	2,479 a	4.2	S
BRS 1501 pearl millet	36 c	0.2	R	115 c	0.5	R
BMX Potência RR soybean	402 a	0.3	R	169 c	0.3	R
URS Altiva white oat	785 b	0.6	R	2,811 a	2.6	S
IPR 89 rye	122 c	0.2	R	180 c	0.2	R
IPR 116 radish	276 c	0.1	R	92 c	0.1	R
Embrapa 29 (Garoa) black oat	464 b	0.6	R	222 c	0.4	R
Iapar 61 Ibiporã black oat	151 c	0.4	R	357 c	1.1	S
Embrapa 139 (Neblina) black oat	473 b	1.0	S	798 b	1.8	S
Ruzigrass	7 c	0.0	R	0.0 c	0.0	I
Santa Clara tomato (control)	1,480 a	5.6	S	2,198 a	9.8	S
URS Corona white oat	0 c	0.0	I	0 c	0.0	I
CV (%)	59.45	52.44		50.35	50.35	

* Means in the column followed by the same letter are not significantly different by the Scott-Knott test ($p < 0.05$). The original data were transformed to $\sqrt{(x + 0.5)}$ before the analysis. CV: coefficient of variation. [1] Plant responses to nematodes were classified according to the Oostenbrink (1966) criteria into susceptible (S), resistant (R) and immune (I).

Santa Clara tomato (control) (2,198 nematodes) (Table 2). For the other plant species, the *M. enterolobii* population density ranged from 92 to 819 nematodes g^{-1} of root. The Santa Clara tomato (control), white lupin, IPR 91 Baili buckwheat, URS Altiva white oat, Iapar 61 Ibiporã black oat and Embrapa 139 (Neblina) black oat were susceptible to the nematode (RF ≥ 1.0), whereas ruzigrass and URS Corona white oat were classified as immune (RF = 0).

In the experiment C (conducted from December 2020 to February 2021, with average temperature of 24.12 ºC), the *M. incognita* population density was higher in URS Altiva white oat (12,994 nematodes), Embrapa 139 (Neblina) black oat (11,221 nematodes) and IPR 91 Baili buckwheat (9,693 nematodes) than in BMX Potência RR soybean (control) (5,338 nematodes) (Table 3). For IPR 116 radish, white lupin, Embrapa 29 (Garoa) black oat, Iapar 61 Ibiporã black oat, BRS 1501 millet, IPR 89 rye and

Table 3. Population density and reproduction factor (RF) of *Meloidogyne incognita* on cover crops at 60 days after inoculation, in two experiments.

Crop	Experiment C (Nov. 2020 to Jan. 2021)			Experiment D (Dec. 2020 to Feb. 2021)		
	Population density	RF	Plant response[1]	Population density	RF	Plant response[1]
White lupin	2,451 b*	4.9	S	-	-	-
IPR 91 Baili buckwheat	9,693 b	3.0	S	36,118 a	5.1	S
BRS 1501 pearl millet	349 c	1.0	S	610 c	2.2	S
BMX Potência RR soybean	5,338 b	9.5	S	18,440 a	22.6	S
URS Altiva white oat	12,994 a	6.4	S	15,185 a	9.3	S
IPR 89 rye	220 c	0.4	R	1,965 c	1.2	S
IPR 116 radish	5,330 b	2.2	S	11,773 b	1.9	S
Embrapa 29 (Garoa) black oat	3,651 b	2.0	S	6,381 b	4.8	S
Iapar 61 Ibiporã black oat	3,355 b	5.1	S	5,550 b	8.5	S
Embrapa 139 (Neblina) black oat	11,221 a	5.1	S	13,739 b	6.9	S
Ruzigrass	36 c	0.1	R	85 c	0.3	R
URS corona white oat	0.0 c	0.0	I	67 c	0.1	R
CV (%)	46.46	40.40		50.65	35.97	

* Means in the column followed by the same letter are not significantly different by the Scott-Knott test ($p < 0.05$). The original data were transformed to $\sqrt{(x + 0.5)}$ before the analysis. CV: coefficient of variation. [1] Plant responses to nematodes were classified according to the criteria of Oostenbrink (1966) into susceptible (S), resistant (R) and immune (I).

ruzigrass, the mean population density ranged from 36 to 5,330 nematodes g^{-1} of root.

The RF was higher for URS Altiva white oat (6.4), Iapar 61 Ibiporã black oat (5.1), Embrapa 139 (Neblina) black oat (5.1) and white lupin (4.9), and equal to or greater than 1 for IPR 91 Baili buckwheat, IPR 116 radish, Embrapa 29 (Garoa) black oat and BRS 1501 millet; therefore, these crops were considered susceptible to *M. incognita*. By contrast, IPR 89 rye and ruzigrass were resistant (RF < 1) to *M. incognita*, while URS Corona white oat was immune (RF = 0) (Table 3).

In the experiment D (conducted from December 2020 to February 2021, with average temperature of 24.12 ºC), the *M. incognita* population density was higher for IPR 91 Baili buckwheat (36,118 nematodes), URS Altiva white oat (12,994 nematodes), Embrapa 139 (Neblina) black oat (13,739 nematodes) and IPR 116 radish (11,773 nematodes) (Table 3). The mean population density for the other cover crops ranged from 67 to 6,381 nematodes g^{-1} of root. Only ruzigrass and URS Corona white oat were resistant (Table 3). The other crops were susceptible (RF ≥ 1), with the highest RF observed for URS Altiva white oat (9.3), Iapar 61 Ibiporã black oat (8.5) and Embrapa 139 (Neblina) black oat (6.9). Among the other species, the RF ranged from 0.1 to 5.1.

In the experiment E (conducted from March to June 2020, with average temperature of 20.9 ºC), the highest *P. brachyurus* population density was observed for IPR 116 radish (357 nematodes) (Table 4). IPR 91 Baili buckwheat, URS Altiva white oat, IPR 89 rye, Embrapa 139 (Neblina) black oat, Iapar 61 Ibiporã black oat, ruzigrass, IPR 116 radish, BRS 1501 millet and Embrapa 29 (Garoa) black oat had population densities ranging from 9 to 102 nematodes g^{-1} of root. In this experiment, only IPR 116 radish, ruzigrass, IPR 91 Baili buckwheat and IPR 89 rye were susceptible to the nematode, according to the classification by Oostenbrink (1966). URS Corona white oat was immune (RF = 0) and the other crops were resistant (RF < 1).

In the experiment F (conducted from September to December 2020, with average temperature of 23.7 ºC), IPR 116 radish (422 nematodes), IPR 89 rye (260 nematodes) and URS Altiva white oat (175 nematodes) had the highest *P. brachyurus* population densities (Table 4). The mean population density in the other crops ranged from 66 to 10,283 nematodes g^{-1} of root. For URS Corona white oat, however, no nematodes were observed. IPR 89 rye, ruzigrass and IPR 116 radish were susceptible to *P. brachyurus* (RF ≥ 1), URS Corona white oat was immune (RF = 0) and the other crops were resistant.

Embrapa 139 (Neblina) black oat was susceptible to *M. enterolobii* in the experiments A and B. Although the results differed between the experiments, white lupin, IPR 91 Baili buckwheat, URS Altiva white oat and Iapar 61 Ibiporã black oat showed RF ≥ 1 in at least one experiment, showing the potential of these crops to multiply the

Table 4. Population density and reproduction factor (RF) of *Pratylenchus brachyurus* on cover crops after 80 days of inoculation, in two experiments.

Crop	Experiment E (Mar. to June 2020)			Experiment F (Sep. to Dec. 2020)		
	Population density	RF	Plant response[1]	Population density	RF	Plant response[1]
IPR 91 Baili buckwheat	102 c*	1.0	S	83 c	0.4	R
BRS 1501 pearl millet	10 e	0.5	R	23 c	0.8	R
BMX Potência RR soybean	178 b	2.8	S	254 b	1.8	S
URS Altiva white oat	83 d	0.5	R	175 b	0.8	R
IPR 89 rye	41 d	1.0	S	260 b	1.1	S
IPR 116 radish	357 a	1.5	S	422 a	1.0	S
Embrapa 29 (Garoa) black oat	9 e	0.2	R	54 c	0.6	R
Iapar 61 Ibiporã black oat	12 e	0.7	R	28 c	0.8	R
Embrapa 139 (Neblina) black oat	30 d	0.8	R	40 c	0.6	R
Ruzigrass	12 e	1.4	S	66 c	1.7	S
URS corona white oat	0 e	0.0	I	0 d	0.0	I
CV (%)	37.90	29.02		31.83	24.14	

* Means in the column followed by the same letter are not significantly different by the Scott-Knott test ($p < 0.05$). The original data were transformed to $\sqrt{(x + 0.5)}$ before the analysis. CV: coefficient of variation. [1] The plant responses to nematodes were classified according to the criteria by Oostenbrink (1966) into susceptible (S), resistant (R) and immune (I).

phytonematode. Previous studies on the response of CD-118, CD-150, BRS-220, CD-104, BRS-Pardela, CD-108 and BRS Tangará white oat to *M. enterolobii* reported resistance (Brida et al. 2018). Therefore, white oat may be used in *M. enterolobii*-infested areas, depending on the cultivar (Brida et al. 2018). Buckwheat was found to be susceptible to *M. enterolobii* in previous studies and should, therefore, be avoided in nematode-infested areas (Khanal & Harshman 2022). No study had yet investigated the response of white lupin to *M. enterolobii*, this being the first report of the crop's susceptibility to *M. enterolobii*.

In the experiments C and D with *M. incognita*, IPR 91 Baili buckwheat, URS Altiva white oat, IPR 116 radish, BRS 1501 millet, Embrapa 29 (Garoa) black oat, Iapar 61 Ibiporã black oat and Embrapa 139 (Neblina) black oat were susceptible to the nematode. Some of these species are known as hosts to *M. incognita*, such as radish (cultivar not reported) (Inomoto & Asmus 2009). In a similar experiment, Iapar 61 Ibiporã black oat and Embrapa 139 (Neblina) black oat were found to be resistant to *M. incognita* (Gabriel et al. 2018). In a previous study (Carneiro et al. 2007), 90, 1449, Takashi, ADR 300, ADR 500 and 1449 millet were deemed resistant to *M. incognita*, as was BRS 1501 millet (Gabriel et al. 2018), in disagreement with the findings of the current study. The differences between these and other experiments highlight the importance of continuously monitoring the susceptibility of species to nematodes, as it can vary depending on the cultivar, environment and nematode population, particularly for oat cultivars, whose RF may vary greatly.

In at least one experiment, white lupin and IPR 89 rye exhibited RF greater than 1 in response to *M. incognita*, demonstrating their susceptibility. Researches on the response of white lupin to *M. incognita* are scarce, and Wrens Abruzzi rye showed to be resistant to *M. incognita* (Timper et al. 2006). IPR 89 rye was susceptible to *P. brachyurus* in the experiments E and F, and IPR 91 Baili buckwheat in the experiment E. To the best of our knowledge, this is the first report of the susceptibility of these crops to *P. brachyurus*.

IPR 116 radish and ruzigrass were also susceptible to *P. brachyurus* in the experiments E and F. Despite being susceptible to nematodes, radish was found to be an unfavorable host under greenhouse conditions (RF = 1.07). Under field conditions, radish significantly reduced the number of *P. brachyurus* (Chiamolera et al. 2012, Vedoveto et al. 2013). As in the current study, some reports have shown that ruzigrass is susceptible to *P. brachyurus* (Queiróz et al. 2014, Debiasi et al. 2016). It is worth mentioning that the *P. brachyurus* reproduction is much higher in maize than in ruzigrass (Queiróz et al. 2014). Therefore, the use of ruzigrass as a rotation crop in constantly monitored areas may provide significant yield gains, given the benefits provided by the plant, such as increased supply of organic matter to the soil (Favoreto et al. 2019).

Most plants that are susceptible to root-knot nematodes (*M. enterolobii* and *M. incognita*) and lesion nematodes (*P. brachyurus*) are frequently used in rotation/succession systems or as cover crop mixes, having a high acceptance by farmers for use in the off-season. Grasses such as white and black oat, legumes, radish and lupin provide multiple benefits to succeeding crops (Silva et al. 2021). Thus, the susceptibility of these plants to nematodes can favor the nematode reproduction and persistence in the field.

BRS 1501 millet and IPR 116 radish were resistant or immune to *M. enterolobii* in the experiments A and B. A previous study showed that these crops are resistant to the nematode (cultivars were not reported) (Rosa et al. 2015). Ruzigrass was resistant or immune to *M. enterolobii* and *M. incognita* in the experiments A, B, C and D, this being the first report of its resistance to *M. enterolobii*. *M. incognita* populations were found to decrease in fields cultivated under ruzigrass (Cunha et al. 2015). Embrapa 29 (Garoa), Embrapa 140, IPFA 99006 and common black oat were found to be resistant to *P. brachyurus* (Borges et al. 2010). In the current study, BRS 1501 millet was resistant to *P. brachyurus* in the experiments E and F. However, previous studies reported the plant to be susceptible to *P. brachyurus*, with RF of 1.02 to 2.10 (Inomoto et al. 2006, Gabriel et al. 2018). URS Corona white oat was the only crop found to be immune or resistant to all the nematode species studied, and this is possibly the first report of the response of this plant to nematodes.

CONCLUSIONS

1. White lupin, IPR 91 Baili buckwheat, URS Altiva white oat, Iapar 61 Ibiporã black oat and Embrapa 139 (Neblina) black oat were susceptible to *Meloidogyne enterolobii*, while BRS 1501 millet,

IPR 89 rye, IPR 116 radish, Embrapa 29 (Garoa) black oat, ruzigrass and URS Corona white oat were resistant or immune;
2. URS Altiva white oat, Iapar 61 Ibiporã black oat, Embrapa 139 (Neblina) black oat, white lupin, IPR 91 Baili buckwheat, IPR 116 radish, Embrapa 29 (Garoa) black oat, IPR 89 rye and BRS 1501 millet were susceptible (reproduction factor ≥ 1) to *M. incognita*, whereas ruzigrass and URS Corona white oat were resistant or immune;
3. IPR 89 rye, ruzigrass, IPR 116 radish and IPR 91 Baili buckwheat were susceptible to *Pratylenchus brachyurus*, while resistance or immunity to the nematode was observed for URS Altiva white oat, Iapar 61 Ibiporã black oat, Embrapa 139 (Neblina) black oat, BRS 1501 millet, IPR 89 rye, Embrapa 29 (Garoa) black oat and URS Corona white oat.

ACKNOWLEDGMENTS

The authors are greatful to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (Capes) - Finance Code 001, for granting a scholarship.

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