RESEARCH/INVESTIGACIÓN

PLANTING DIFFERENT CROPS IN SUCCESSION TO MANAGE *PRATYLENCHUS ZEAE* IN SUGARCANE

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ABSTRACT

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The study assessed the effect of crop rotation with economically important plant species on *Pratylenchus zeae* damage to sugarcane. Two experiments were conducted, one in October 2011 and another in January 2012. The experiments followed a completely randomized design with 10 treatments, which included three rice genotypes (Ana 9001, Iapar 9, and Ecco CL hybrid), millet cv. AMN-17, crotalaria, cotton cv. IPR 140, sunflower cv. Syn 045, fallow, sugarcane cv. RB 72454 and the hybrid maize BRAS 3010. Sugarcane was cultivated for 90 days and followed by different rotation crops for 90 days. Next, the plants were cultivated for 180 days to finish their growth cycles. The plants were inoculated with 2,000 *P. zeae.* Sugarcane root mass, root population of *P. zeae*, nematode population in 100 cm^3 soil, total nematode population, and Reproduction Factor (RF) were assessed at the end of the experiment. Among all species and cultivars, crotalaria and rice cultivar Ana 9001 had the lowest nematode RF. None of the economically important crops were recommended for use in rotation systems with sugarcane because all of them had RF values similar to those of sugarcane and maize.

Key words: cotton, crotalaria, fallow, rice, rotation, sunflower

RESUMO

Santana-Gomes, S. M., C. R. Dias-Arieira, F. Biela, M. Ragazzi, S. S. Baldisera e R. P. Schwengber. 2019. Sucessão de culturas no manejo de *Pratylenchus zeae* em cana de açúcar. Nematropica 49:63-70.

O trabalho teve como objetivo avaliar o efeito da sucessão de culturas, com espécies de importância econômica, sobre a população de *Pratylenchus zeae* na cultura da cana-de-açúcar. Dois experimentos foram conduzidos em épocas diferentes, outubro/2011 e janeiro/2012, em delineamento inteiramente casualizado, com dez tratamentos, sendo três genótipos de arroz (Ana 9001, Iapar 9 e híbrido Ecco CL), milheto cv. AMN-17, crotalária, algodão cv. IPR 140, girassol cv. Syn 045, pousio, milho híbrido BRAS 3010 e cana cv. RB 72454, usados como testemunhas. Cultivou-se primeiramente a cana cv. RB 72454 por 60 dias, seguida das diferentes espécies vegetais (tratamentos) e, por fim, cana cv. RB 72454 novamente, finalizando o ciclo de sucessão. As unidades experimentais consistiram em vasos com capacidade para 1 L, com duas plantas, cultivadas em solo arenoso, inoculado, inicialmente, com 2000 espécimes de *P. zeae* por vaso. Ao final do experimento, avaliou-se massa de raiz da cana, população de *P. Zeae*/g de raiz, população em 100 cm^3 de solo, população total e FR. Não houve diferença significativa entre os tratamentos para a variável massa fresca, no experimento 2. Dentre as espécies estudadas, a crotalária e o arroz 'Ana 9001' possibilitaram menor multiplicação do nematoide. Das culturas de interesse econômico, nenhuma apresentou resultados que permita a indicação para cultivo em sistema de sucessão com a cana-de-açúcar, visto que os FRs dos tratamentos variaram de 0.0 a 2.6, próximo ao da cana e do milho.

Palavras-chave: arroz, algodão, crotalaria, girasol, pousio, rotação

INTRODUCTION

Sugarcane (*Saccharum* spp.) cultivation is expanding in Brazil. Sugarcane has been cultivated as monoculture crop due to the high demand for sugar and alcohol. However, since sugarcane is a semi-perennial crop, the plant supports the development of large nematode populations that hinder yield (Cadet and Spaull, 2005).

Among all nematodes associated with sugarcane in Brazil, *Pratylenchus zeae* Graham stands out as the most important species because *P. zeae* causes significant economic losses due to its wide host range (Moura *et al.*, 1990; Novaretti *et al.*, 1998; Santos *et al.*, 2012). The nemataode is endemic in virtually all sugarcane-producing regions of Brazil. *Pratylenchus* species were detected in 85% of the 74 sugarcane samples assessed by Severino *et al.* (2010) in Northeastern Parana State and of the positive samples, *P. zeae* was found in 73%.

Novaretti *et al.* (1998) conducted a study in commercial sugarcane production areas in São Paulo State and reported large populations of *P. zeae.* Likewise, Dinardo-Miranda *et al.* (2003b) detected the same populations in Piracicaba, SP. Large *P. zeae* populations were also found in sugarcane crops in Pernambuco State. This species was also found in sugarcane plantations in other countries such as South Africa (Berry *et al.*, 2008) and Australia (Stirling *et al.*, 2001).

The use of sugarcane cultivars resistant to the main parasitic nematodes is the most desired control strategy; however, commercial cultivars combining the desired resistance and yield remain scarce (Dinardo-Miranda, 2005). Accordingly, crop rotation should be an alternative to combat nematodes (Ferraz *et al.*, 2010).

The objective of the study was to assess the effect of different economically important crops planted in succession on populations of *P. zeae*.

MATERIALS AND METHODS

The experiment was conducted in the greenhouse on the Experimental Farm of State University of Maringa, *Campus* Umuarama, Parana, Brazil. Experiment 1 was performed from October 2011 to October 2012 at mean minimum and maximum temperatures at 18.3°C and 28.8ºC, respectively. Experiment 2 was conducted from November 2011 to November 2012 at minimum and maximum temperatures at 18.3°C and 29ºC, respectively. Data were collected at IAPAR meteorological station, Umuarama County. The research followed a completely randomized design with 10 treatments and 4 replications.

The experimental units consisted of 1 L pots containing 800 g of substrate composed of sandy soil samples autoclaved for 2 hr at 121ºC. Soil physical composition was 58.9% sand, 22.2% clay, and 18.9% silt. Soil chemical composition was pH_{CaCl2} = 4.76; P = 7.66 mg/dm^3; K = 0.30 $cmol_c$ /dm^3; Organic matter (M.O.) = 2.86 g/dm^3; Cation exchange capacity (CEC) = 13.87 $cmol_c$ /dm^3 and Base saturation (V%) = 51.77%.

Initially, two seedlings of sugarcane cv. RB72454 were transplanted to each pot. Sugarcane stalks were cut to one bud. Stalks were stored in a germination box with absorbent paper and watered for 7 days at approximately 28°C and then transferred to the pots. Plants were inoculated with 2,000 *P. zeae* after 15 days. Inoculum was obtained from a pure culture grown on hybrid maize BRAS 3010 and extracted through the method by Coolen and D'Herde (1972). The number of nematodes was determined by using the nematode counting slide and a dissecting microscope to count all the infective stages, i.e., mobile stages capable of penetrating and leaving attacked vegetal tissues throughout plant life (Ferraz and Brown, 2016).

The shoot of the sugarcane plant in each pot was discarded after 90 days and rotation crops were sown in each pot as follows: millet (*Pennisetum americanun* L.) AMN-17, rice genotypes (*Oriza sativa* L.) Ana 9001, Iapar 9 and hybrid Ecco CL, cotton (*Gossypium hirsutum* L.) cv. IPR 140, sunflower (*Helianthus annuus* L.) Syn 045, crotalaria (*Crotalaria juncea*), and fallow in association with sugarcane (*Saccharum* spp.) cv. RB72454 and the hybrid maize (*Zea may*s L.) BRAS 3010. Sugarcane and maize were used as control treatments. The shoot of the rotation plant was cut and discarded after 90 days while the root system remained in the soil. Subsequently, two cv. RB72454 seedlings were transferred to each pot and left to grow for 180 days. According to the chemical analysis, the soil was fertilized with 02-16-06 (1 g pot). The pots were irrigated through sprinkling on a daily basis.

The root system of each treatment and 100 cm^3 of soil were collected at the end of the experiment in order to determine the final population of *P. zeae.* Nematodes were extracted from both roots and soil according to the methodologies described by Hussey and Barker (1973), adapted by Bonetti and Ferraz (1981), and Jenkins (1964), respectively. The nematodes were counted with the aid of a dissecting microscope. The number of nematodes in the root was divided by fresh root weight to provide the number of nematodes per gram root. Total population was calculated by summing the nematodes collected from the soil and those from the roots. Values corresponding to the initial (Pi) and final (Pf) population were plotted through the formula RF = (Pf/Pi), where RF is the reproduction factor (Oostenbrink, 1966). Original data were transformed into $\sqrt{x+1}$ for the analysis of variance. Means were compared through Scott-Knott test (1974) at 5% probability level in the SISVAR statistical software (Ferreira, 2008).

RESULTS AND DISCUSSION

Overall, no differences in sugarcane root dry mass were detected among treatments (P>0.05) (Table 1). Crotalaria and fallow lowered sugarcane root mass in experiment 1. However, these two treatments and sunflower had the lowest levels of nematode/g root. Rice cv. Iapar 9 had a RF equivalent to sugarcane and maize. All other rotation crops showed RF values lower than that of the sugarcane and maize controls. Millet, despite having mean nematodes/g root lower than that of the sugarcane and maize treatment showed higher RF than other rotation plants. All other treatments in experiment 2 showed number of nematodes/g root equal to, or higher than, sugarcane and maize, except for crotalaria (Table 1).

All treatments, in both experiments, reduced the number of nematodes/100 cm^3 soil when compared to the sugarcane and maize, except for millet, rice Ecco CL, and rice Iapar 9 (Table 1). Lower nematode population densities were found in crotalaria than in sugarcane or maize (Table 1). Consequently, RF was also lower in crotalaria treatment with RF values ranging from 0.0 to 0.3 (Table 1).

Based on comparisons between different rice cultivars, Ana 9001 was the only cultivar with RF values lower than 1 in both experiments (0.6 and 0.9, in experiments 1 and 2, respectively). Rice cultivar Ecco CL had an RF of 0.4 and 2.6 and Iapar 9 had an RF of 1.5 and 1.8 in experiments 1 and 2, respectively (Table 1).

Fallow resulted in one of the lowest sugarcane root dry mass values in experiment 1 possibly due to reduced fertility caused by lower organic matter accumulation and nutrient retention in the soil (Ceinfo, 2013).

Maize was susceptible to *P. zeae.* The RF associated with maize ranged from 1.4 to 1.7, similar to previous studies (Patel *et al.*, 2002; Inomoto *et al.*, 2011; Biela, 2013). Inomoto *et al.* (2011) observed that maize cv. Zélia promoted significant *Pratylenchus* spp. population increase and led to increased *P. zeae* percentage in areas subjected to crop rotation with cotton, soybean and cowpea. According to Patel *et al.* (2002), maize parasitism by *P. zeae* causes shoot and root mass reduction, as well as lower plant height and reduced chlorophyll content (Monteiro, 1963; Lordello *et al.*, 1992).

Sugarcane plants grown as monoculture crop in experiment 1 recorded greater total nematode populations with RF values greater than 1 in both experiments. Maize is susceptible to *P. zeae,* one of the most harmful sugarcane parasitic nematodes in Brazil (Dinardo-Miranda and Ferraz 1991; Dinardo-Miranda *et al.*, 2003a). Santos *et al.* (2012) demonstrated the susceptibility of maize cv. RB 72454 (RF = 2.6) to *P. zeae* as well as of other 29 cultivars. Sugarcane susceptibility to this nematode was reported by many authors in Brazil

Table 1. Root fresh weight (RFW) and *Pratylenchus zeae* population in sugarcane crops grown for 180 days after rotation with different crops.

	Experiment 1					Experiment 2				
Treatment	RFW (g)	NGR[u]	NS[v]	TP[w]	RF[x]	RFW (g)	NGR[u]	NS[v]	TP[w]	RF[x]
Maize	7.5 a[y]	408 a	314 b	3374 b	1.7	10.0 ns[z]	248 c	262 b	2742 c	1.4
Sugarcane	10.0 a	507 a	618 a	5688 a	2.8	10.0	223 c	519 a	2749 c	1.4
Millet	7.2 a	228 b	37 d	1679 c	0.8	10.0	264 c	666 a	3306 b	1.6
Rice Ana 9001	7.0 a	138 c	138 c	1104 c	0.6	9.6	188 c	94 c	1928 c	0.9
Rice Ecco CL	7.2 a	90 c	153 c	801 c	0.4	9.0	537 a	311b	5144 a	2.6
Rice Iapar 9	6.8 a	405 a	173 c	2927 b	1.5	10.0	331 b	253 b	3563 b	1.8
Cotton	9.3 a	146 c	19 d	1376 c	0.7	10.0	242 c	48 c	2468 c	1.2
Sunflower	8.6 a	0 d	0 e	0 d	0.0	10.0	237 c	144 c	2514 c	1.2
Crotalaria	3.4 b	0 d	36 d	36 d	0.0	9.4	66 d	63 c	683 d	0.3
Fallow	3.2 b	0 d	0 e	0 d	0.0	10.0	393 b	94 c	4024 b	2.0
CV (%)	27.5	16.5	26.9	21.4	-	5.8	11.2	20.2	10.8	-

[u]Nematodes per root gram.
[v]Nematodes in 100 cm^3 of soil.
[w]Total nematode population.
[x]Reproduction factor = Pf/Pi (Oostenbrink, 1966).
[y]Means with the same letter were not significantly different in Scott-Knott at 5% probability. Means were transformed into $\sqrt{x+1}$.
[z]ns = non-significant differences between treatments. CV = coefficient of variation.

(Moura *et al.*, 1999; Blair, 2005; Moura and Oliveira, 2009; Severino *et al.*, 2010). In other countries, such as India and South Africa, *P. zeae* also causes considerable damage to sugarcane crops (Mehta and Sundararaj, 1995; Stirling *et al.*, 2001).

The number of nematodes gram millet root in experiment 1 was statistically lower than that of maize, corroborating Biela (2013). However, mean number of *P. zeae* in experiment 2 did not differ from the control treatments. RF ranged from 0.8 to 1.6 in the both experiments. Millet RF after 90 days was 1.39 in the study by Biela (2013). Despite finding RF<1 for millet in one of our experiments, we believe RF was influenced by weather conditions.

Although rice cultivars showed low population growth in experiment 1, cultivars Ecco CL and Iapar 9 were susceptible to *P. zeae* in experiment 2. The RFs were equal to 2.6 and 1.8, respectively. Only cultivar Ana 9001 had a RF lower than 1 in both experiments. However, we must be careful to recommend these cultivars for areas infested with *P. zeae*, since the recorded value was close to 1 (0.9). Previous studies evidenced that the rice cultivars were susceptible to *P. zeae* with RF values equal to 3.86, 4.38, and 6.54 for Ecco CL, Ana 9001, and Iapar 9, respectively (Biela, 2013). Plowright *et al.* (1999) found that all *Oryza glaberrima* Steud and *O. sativa* cultivars tested were susceptible to *P. zeae*. Sahoo and Sahu (1993) found *P. zeae* eggs, adults, and juveniles in the cortical region of rice Arnapurna roots.

The RF of *P. zeae* in cotton was close to 1. RF ranged from 0.7 to 1.2 in both experiments. However, the number of nematodes/g root was lower than in the maize and sugarcane treatments in only one of the experiments, indicating the need of caution to use the studied cultivar in areas infested with this nematode. There are few studies on cotton susceptibility to *P. zeae,* but Fortuner (1976) reported lesion nematodes in this crop.

A study in cotton-growing areas in Arkansas analyzed approximately 101 soil samples/year for 3 years and detected *P. zeae* in only one sample (Robbins *et al.*, 1989). Inomoto *et al.* (2011) observed that cotton cv. Delta Opal in crop rotation in soil comprising mixed *Pratylenchus* populations led to decreased *P. zeae* population in comparison to *P. brachyurus.* A population of *Pratylenchus* was comprised from 10 to 20% to less than 10% of *P. zeae*. Thus, it is important to investigate and elucidate the susceptibility of different cotton cultivars to *P. zeae* to identify potential rotation cultivars.

Sunflower cultivars used in rotation with sugarcane are potentially promising. The nematode was not detected in the first experiment and the nematode population density did not differ from sugarcane in the experiment 2. Bolton and De Waele (1989) found that all the sunflower hybrids AS 504, PNR 7204, SO 171, and SO 444 behaved as non-hosts or as poor hosts to *P. zeae*.

Crotalaria recorded the lowest means for variables analyzed in all treatments. Nematode management based on the use of non-host plants has been adopted in many cropping systems. Some producers used crop rotation with leguminous crops in areas traditionally cultivated with sugarcane, because legumes increase the nutrients in the soil. *C. juncea* is the most commonly used species in these rotations because of its high yield. (Cáceres and Alcarde, 1995). The sugarcane-crotalaria-sugarcane rotation system used in a soil naturally infested with a mix of *P. zeae* and *P. brachyurus* in Goianesia county reduced the nematode populations by approximately 48% and kept these populations at relatively lower levels for longer - approximately 4 months - in comparison to other assessed systems (Oliveira *et al.*, 2008).

However, sugarcane cultivation for 6 months preceded by *C. juncea* incorporation in a recovery sugarcane-plantation site infested with *P. zeae* resulted in means equal to those of the control (sugarcane-fallow-sugarcane) (Oliveira *et al.*, 2008). Rosa *et al.* (2003) found *C. juncea* cultivation increased *P. zeae* populations. Nevertheless, crop rotation with *C. juncea* increased sugarcane yield by 20.8 t/ha (Dinardo-Miranda and Gil, 2005). *Crotalaria. juncea* effectively controlled other important nematodes in sugarcane, such as *M. incognita* and *M. javanica*. Soil incorporation of crotalaria stimulated the growth of natural nematode-enemy populations (Wang *et al.*, 2002). According to Santana *et al.* (2012), *C. spectabilis* cultivation in sandy or clay soil significantly reduced *P. zeae* population after 60 or 110 cultivation days.

Although RF was equal to 0 in fallow (experiment 1), fallow in experiment 2 showed population maintenance in non-planted soil when the total population was larger than in maize and sugarcane treatments. The RF was equal to 2.0. The efficiency of clean and prolonged fallow (from 12 to 42 months) to control *P. zeae* in sugarcane was demonstrated by Stirling *et al.* (2001). On the other hand, Moura and Oliveira (2007) observed that, in fallow with floristic composition in balance with soil microfauna, the flora tended to have low parasitic nematode populations.

Therefore, fallow should be avoided in sugarcane plantation areas recording low yield rates, even at appropriate fertility conditions, because weed species could be the source of inoculum for the first sugarcane crop to be grown. Moreover, this practice is not recommended due to increased soil erosion, reduced fertility caused by poor soil organic matter content, and endomycorrhizal fungal population decline (Ceinfo, 2013).

Crotalaria reduced the population of *P. zeae* and can be recommended for crop-rotation systems with sugarcane. It is necessary to conduct further studies to select plants to assure the economic return from crop rotation because research about alternative managements for *P. zeae* remain scarce.

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