STATUS OF WINTER CEREALS, OTHER ROTATION CROPS AND COMMON WEEDS AS HOSTS OF LESION NEMATODE (*PRATYLENCHUS ZEAE*)

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Abstract

LESION nematode (*Pratylenchus zeae*) occurs in almost every sugarcane field in Queensland and is perhaps the most important of a community of nematode pests that cost the Australian sugar industry an estimated $82 million/annum in lost production. Legumes such as soybean and peanut are relatively poor hosts of the nematode and, when they are used as rotation crops in the sugarcane farming system, populations of *P. zeae* are markedly reduced. This paper provides data on the host status of other rotation crops that might have a place in the sugarcane farming system, together with some common weeds. The capacity of *P. zeae* to multiply on various plants was assessed after 70 days in pots at temperatures suitable for nematode reproduction, with multiplication factors calculated as (Pf/Pi), where Pf was the final nematode population density and Pi the initial inoculum density. Sugarcane and forage sorghum had the highest multiplication factors (Pf/Pi >40), whereas the nematode population on most other plants increased 5 to 13 times. Some cultivars of wheat, oats and Rhodes grass had multiplication factors of only 3 or 4 and three crops (*Setaria* cv. Splenda, barley cv. Grimmett and cowpea cv. Red Caloona) were non-hosts (Pf/Pi <1). In field trials, canola, linseed and chickpea did not increase populations of *P. zeae* when grown as winter crops at Farnsfield, while wheat and field pea crops grown during winter at Bundaberg did not diminish the level of nematode control obtained from previous crops of peanut or soybean. These results suggest that breaking the sugarcane monoculture with a summer legume followed by a winter crop (e.g. wheat, barley, oats, linseed, canola, field pea or chickpea) will not markedly affect the level of nematode control that is achievable with a legume crop alone.

Introduction

Plant-parasitic nematodes are insidious pests of sugarcane: the symptoms they produce on roots are relatively non-specific while above-ground effects are difficult to recognise because non-infested crops are never available for comparison (Stirling and Blair, 2000). Nevertheless, the role of nematodes in contributing to the yield decline syndrome of sugarcane is now well documented. Large and consistent yield responses were obtained when nematode populations were reduced by soil fumigation, crop rotation and fallowing (Stirling *et al.,* 2001) and the results of 16 field experiments in south and central Queensland showed that plant and ratoon crop yields increased by 15.3 and 11.6%, respectively, when nematodes were kept under control with nematicides (Blair and Stirling, 2007). These results suggest that nematode pests are currently costing the Australian sugar industry about $82 million per annum in lost production.

Lesion nematode (*Pratylenchus zeae*) is probably the most important of the community of plant-parasitic nematodes that are commonly found in sugarcane fields. It occurs at high population densities in a wide range of soil types (Blair *et al.,* 1999a, 1999b) and was the predominant plant parasite at many of the sites where sugarcane responded to nematicide treatment (Blair and Stirling, 2007). Legumes such as soybean and peanut are relatively poor hosts of *P. zeae* and, when used as rotation crops in a sugarcane farming system, they markedly reduce populations of the nematode (Stirling *et al.,* 2001, 2002, 2006a, 2006b). However, there are limited data on the host status of other rotation crops that might have a place in the sugarcane farming system, while the capacity of common weeds to host *P. zeae* is also not known. This paper provides that information. A secondary objective was to determine whether the inclusion of a winter rotation crop following a summer legume affected the level of nematode control obtained with the legume crop alone.

Methods

Host status in pots

Four replicate pots filled with 1.4 L of pasteurised sand were planted to one of 21 plant species and cultivars (Table 1). Sugarcane was planted as one single-eye sett, large-seeded crops were established using 1–3 seeds/pot (depending on the amount of biomass expected), and about 15 seeds were sown for small-seeded grasses. Other plants were established from vegetative material.

Ten days after planting, each pot was inoculated with 600 *P. zeae* (initial inoculum density, Pi). Plants were then grown for 70 days (from 22 November 2007 until 31 January 2008), when temperatures in the greenhouse ranged from about 22ºC at night to 35ºC during the day. At harvest, soil was shaken from the roots and nematodes were extracted from a 200 mL soil sample using a standard nematode extraction tray (Whitehead and Hemming, 1965). Roots were washed, placed in a mister and nematodes moving from the roots were collected after 5 days. The total number of nematodes per pot (final population density, Pf) was determined by multiplying the soil count by 7 (to calculate the number of nematodes in 1.4 L of soil) and adding the count from roots.

Field experiment at Farnsfield

This experiment was established at Farnsfield (about 15 km north of Childers) in a sandy soil that had grown peanut (*Arachis hypogaea*) cv. Menzies as a rotation crop following sugarcane.

On 24 May 2007, after the peanuts had been harvested, the field was cultivated and four replicate plots (20 × 4.8 m) of four treatments (bare fallow, canola (*Brassica napus*) cv. Dune, chickpea (*Cicer arietinum*) cv. Moti and linseed (*Linum usitatissimum*) cv. Glenelg) were set out in a randomised block design.

The winter rotation crops were harvested on 22 October 2007 and then sugarcane (cv. Q208$^{(\dagger)}$) was replanted.

Soil samples (ten cores 25 mm in diameter /plot) were collected at a depth of 0–20 cm prior to planting the winter crops, before sugarcane was replanted and when the sugarcane was about 5 months old.

Nematodes were extracted from 200 mL soil samples using the method described above for the pot experiment.

Field experiment at Bundaberg

This experiment was established in August 2008 at a site near Bundaberg with a sandy clay loam soil. After sugarcane was harvested, lime was applied at 3 t/ha and plots, each 20 × 9 m, were established to accommodate rotation crops of peanut cv. Holt, soybean (*Glycine max*) cv. Fraser, wheat (*Triticum aestivum*) cv. Clearfield Janz, field pea (*Pisum sativum*) cv. Maki and Rhodes grass (*Chloris gayana*) cv. Katambora.

The seven treatments in the experiment (peanut/wheat, peanut/field pea, soybean/wheat, soybean/field pea, Rhodes grass pasture, sugarcane (ratooned after the crop was harvested in August 2008) and bare fallow maintained with herbicides) were replicated three times in a randomised block design.

Mill mud (150 wet tonnes/ha) was applied to Rhodes grass plots and then peanut, Rhodes grass and soybean were planted in late November 2008. Peanuts and soybeans were harvested in April 2009 and the winter crops (wheat or field pea) which followed were planted on 2 June 2009 and harvested on 5 October 2009.

Soil samples (a composite of 10 cores/plot to a depth of 10 cm) were collected on 22 April and 9 October 2009 and nematodes were extracted from 200 mL samples using methods described previously.

At the last sampling date, a composite sample of wheat roots (two plants from each of three replicate plots) was also collected and nematodes were extracted by placing 9 g (fresh weight) of roots in a mist cabinet for 7 days.

Occasional samples

In September 2007, soil and root samples were collected from three mature barley (*Hordeum vulgare*) crops in the Farnsfield area. At two of the sites, barley had been grown following peanut while barley followed soybean at the other site. Nematodes were extracted from soil and roots using methods described for the pot experiment.

Results

Host status in pots

Plants varied markedly in their capacity to host *P. zeae* (Table 1). Sugarcane and forage sorghum were excellent hosts, with multiplication factors (Pf/Pi) >40, whereas the nematode population increased 5 to 13 times on most other plants (Table 2).

Some cultivars of wheat, oats and Rhodes grass had multiplication factors of only 3 or 4 and three crops (*Setaria* cv. Splenda, barley cv. Grimmett and cowpea cv. Red Caloona) were non-hosts (Pf/Pi <1).

Most of the plants grew well, with summer forage crops such as Rhodes grass, *Setaria sphacelata*, forage sorghum, buffel grass and green panic producing the most root biomass (Table 2).

However, crops that are normally grown during winter (e.g. wheat, barley and oats) grew well initially and then flowered, so they had matured by the time the experiment was harvested.

Thus the amount of root biomass varied considerably between plant species and this affected nematode population densities/g root (Table 2).

Table 1—Population densities of *Pratylenchus zeae* 70 days after potted plants were inoculated with 600 nematodes.

Plant	Common name	Cultivar	Final no. of *P. zeae*/pot (Pf)[A]	
Sorghum bicolor	Forage sorghum	Pac 8350	4.566	(36813)
Sorghum bicolor	Forage sorghum	Jumbo	4.526	(33574)
Saccharum officinarum	Sugarcane	Q208(ɬ)	4.423	(26485)
Axonopus compressus	Carpet grass	–	3.887	(7709)
Cenchrus ciliaris	Buffel grass	USA	3.881	(7603)
Avena sativa	Oats	Nugene	3.855	(7161)
Zea mays	Maize	H5	3.772	(5916)
Digitaria decumbens	Pangola grass	–	3.679	(4775)
Triticum aestivum	Wheat	Strezlecki	3.668	(4656)
Panicum maximum	Green panic	–	3.577	(3776)
Glycine max	Soybean	6785	3.550	(3548)
Brachiaria decumbens	Signal grass	–	3.447	(2799)
Hordeum vulgare	Barley	Dictator	3.403	(2529)
Triticum aestivum	Wheat	Sunvale	3.403	(2529)
Avena sativa	Oats	Moola	3.392	(2466)
Chloris gayana	Rhodes grass	Katambora	3.308	(2032)
Cynodon dactylon	Couch grass	–	3.175	(1496)
Cyperus rotundus	Nutsedge	–	3.040	(1096)
Setaria sphacelata	Setaria	Splenda	2.692	(492)
Hordeum vulgare	Barley	Grimmett	2.181	(152)
Vigna unguiculata	Cowpea	Red Caloona	2.025	(106)
LSD (P=0.05)			0.381	

[A] Transformed data [$\log_{10}$ (no. nematodes +1) were analysed, with back-transformed means given in parentheses

Table 2—Root biomass, nematodes/g root and multiplication factors (Pf/Pi) for *Pratylenchus zeae* when potted plants were inoculated with 600 nematodes (Pi) and final nematode population densities (Pf) were determined after 70 days.

Plant	Common name	Cultivar	Dry wt. roots (g)	*P. zeae* /g root	Pf/Pi
Sorghum bicolor	Forage sorghum	Pac 8350	7.5	4943	61.3
Sorghum bicolor	Forage sorghum	Jumbo	5.7	6708	56.0
Saccharum officinarum	Sugarcane	Q208[A]	4.0	7814	44.1
Axonopus compressus	Carpet grass	–	1.2	7352	12.8
Cenchrus ciliaris	Buffel grass	USA	7.0	11118	12.7
Avena sativa	Oats	Nugene	0.8	10697	11.9
Zea mays	Maize	H5	2.2	3116	9.9
Digitaria decumbens	Pangola grass	–	1.7	3523	8.0
Triticum aestivum	Wheat	Strezlecki	0.5	10196	7.8
Panicum maximum	Green panic	–	6.5	641	6.3
Glycine max	Soybean	6785	1.9	2540	5.9
Brachiaria decumbens	Signal grass	–	4.4	737	4.7
Hordeum vulgare	Barley	Dictator	0.4	8687	4.2
Triticum aestivum	Wheat	Sunvale	0.5	6217	4.2
Avena sativa	Oats	Moola	0.5	6960	4.1
Chloris gayana	Rhodes grass	Katambora	8.2	269	3.4
Cynodon dactylon	Couch grass	–	0.8	3131	2.5
Cyperus rotundus	Nutsedge	–	4.0	323	1.8
Setaria sphacelata	Setaria	Splenda	7.4	74	0.8
Hordeum vulgare	Barley	Grimmett	0.7	283	0.3
Vigna unguiculata	Cowpea	Red Caloona	1.2	154	0.2
LSD (P=0.05)			0.99		

Field experiment at Farnsfield

At the time the winter rotation crop was planted and the fallow treatment was established (i.e. soon after the peanut rotation crop was harvested), populations of *P. zeae* were relatively low (Table 3).

Populations remained at much the same level after three months of a winter crop or fallow and then increased markedly when sugarcane was planted. *Meloidogyne javanica* and *Paratrichodorus minor*, the two other plant-parasitic nematodes present at the site, responded in the same way (Table 3).

Field experiment at Bundaberg

At the time peanuts and soybeans were harvested, populations of *P. zeae* were relatively high on Rhodes grass and sugarcane and had been markedly reduced by the legumes and bare fallow (Table 4).

Populations in all treatments then declined during winter but the nematode control that was apparent following peanut and soybean was maintained following wheat or field peas.

Very low numbers of nematodes (0.7 and 1.8 *P. zeae*/g root) were obtained from wheat roots collected after the crop was harvested.

Table 3—Populations of plant-parasitic nematodes[A] following a summer crop of peanuts, before planting and after harvest of winter rotation crops (June and October 2007, respectively), and in March 2008, 5 months after planting sugarcane.

	June 2007	October 2007	March 2008
	No. *Pratylenchus zeae*/200 mL soil		
Fallow	18	7	566
Canola	8	6	474
Chickpea	18	5	290
Linseed	12	4	578
	No. *Meloidogyne javanica*/200 mL soil		
Fallow	0	0	414
Canola	0	0	268
Chickpea	2	1	345
Linseed	0	0	105
	No. *Paratrichodorus minor*/200 mL soil		
Fallow	0	0	81
Canola	1	1	102
Chickpea	1	1	118
Linseed	1	0	118

[A] For each nematode at each sampling time, differences between treatments were not significant

Populations of spiral nematode (*Helicotylenchus dihystera*) were higher following soybean than other crops (Table 4) and although numbers declined in winter, this difference was still apparent after the winter crops were harvested.

Stunt nematode (*Tylenchorhynchus annulatus*) was also present at the site but populations were low and were not affected by the cropping treatment at either sampling time (data not shown).

Table 4—The impact of sugarcane, various summer and winter crops and a 15 month bare fallow on nematode population densities in a field at Bundaberg.

Summer crop	Winter crop	*Pratylenchus zeae* /200 mL soil		*Helicotylenchus dihystera* /200 mL soil	
		After summer crop	After winter crop	After summer crop	After winter crop
Peanut	Wheat	102 b	5 bc	43 c	10 b
Peanut	Field pea	47 bc	9 b	91 c	12 b
Soybean	Wheat	14 bc	2 c	2022 a	183 a
Soybean	Field pea	7 bc	14 b	1513 ab	199 a
Rhodes grass	Rhodes grass	1584 a	500 a	105 c	2 c
Sugarcane	Sugarcane	616 a	165 a	487 c	37 ab
Fallow	Fallow	83 bc	11 b	95 c	21 b

Data are back-transformed means of transformed data [$\log_{10}$ (no. nematodes +1). In each column, numbers followed by the same letter are not significantly different (P = 0.05)

Occasional samples

Numbers of *P. zeae* in three soil samples collected following barley crops were very low (<2 nematodes/200 mL soil). The nematode was not recovered from barley roots.

Discussion

P. zeae is widespread in tropical and subtropical regions of the world and is commonly found on sugarcane, maize, sorghum, rice and various other grasses (Fortuner, 1976). Our pot experiment with an Australian population confirmed that grasses are the preferred host for this nematode. Over a period of 70 days (which is sufficient time for about two nematode generations), populations increased 44-61 times on forage sorghum and sugarcane, while multiplication factors on carpet grass, buffel grass, maize, pangola grass and one variety of oats ranged from 8 to 13. The high nematode multiplication rate on sugarcane and other grasses was not unexpected, as *P. zeae* commonly occurs at high population densities in Australian sugarcane fields (Blair *et al.,* 1999a, 1999b) and populations do not decline markedly when grassy weeds and volunteer sugarcane predominate during the fallow period (Stirling *et al.*, 2007).

Given that the known host range of *P. zeae* includes non-grass crops such as tobacco, soybean, peanut, sweet potato, tomato and various weeds (Fortuner, 1976), it was not surprising that most of the other plants included in our experiment also hosted the nematode. However, all were much poorer hosts than forage sorghum and sugarcane.

Soybean and peanut are important rotation crops in the Australian sugar industry and their role in reducing populations of *P. zeae* is now well recognised (Stirling *et al.,* 2001, 2002, 2006a, 2006b). *P. zeae* is not a pest of either crop (Sikora *et al*., 2005; Dickson and DeWaele, 2005) and our results provide further evidence that soybean and peanut are relatively poor hosts of the nematode. Nevertheless, some reproduction does occur on soybean and this may explain why populations of *P. zeae* are not always reduced to very low levels by a single soybean crop (Stirling *et al.,* 2007). Since host status is likely to vary with cultivar and some soybean cultivars are excellent hosts (Acosta and Malek, 1979), it may be worthwhile checking cultivars for resistance to *P. zeae* before they are introduced into the sugarcane farming system.

In some sugarcane-growing areas, it is logistically possible and economically worthwhile to grow both legumes and cereals in the break between sugarcane crops. Thus one objective of this work was to determine whether inclusion of wheat, barley or oats in the rotation would exacerbate problems caused by *P. zeae*. We found very high nematode population densities in the roots of all three cereals in pots, probably because the experiment was done in mid summer when temperatures were ideal for nematode multiplication. Acosta and Malek (1979) demonstrated that temperatures around 30°C are optimal for *P. zeae*, as nematode population densities increased 138 and 33 times in 75 days at 30 and 35°C, respectively, compared with only 7.5 times at 25°C. Winter soil temperatures are normally less than 20°C in southern

cane-growing areas of Australia, and will therefore limit multiplication of *P. zeae* during the period when cereals are likely to be grown. Thus in subtropical cane-growing areas, it should be possible to grow cereals or any other crop during winter and still retain the nematode control that is obtainable from a summer legume crop. That conclusion is supported by our results from the field.

Although this study focused primarily on *P. zeae*, results from our field trials suggested that inclusion of a winter crop in the rotation is not likely to increase problems caused by other plant-parasitic nematodes. *M. javanica* and *P. minor* did not multiply during winter at the Farnsfield site, probably because reproduction was also limited by temperature. Populations of *H. dihystera* were relatively high following wheat and field pea at the Bundaberg site, but this was probably due to carryover from the previous soybean crop rather than multiplication during winter. Even if some reproduction did occur, this is not a concern, as *H. dihystera* does not cause economic damage to sugarcane (Spaull and Cadet, 1990).

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