THE ROLE OF VARIETIES AND NEMATICIDES IN CONTROLLING PLANT-PARASITIC NEMATODES IN ISIS MILL CANE SUPPLY AREA

By

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KEYWORDS: Varieties, Plant Parasitic Nematodes, Nematicides.

Abstract

PLANT-PARASITIC NEMATODES (PPN) adversely affect sugarcane productivity. PPN, particularly root-knot nematodes (RKN), are common in sandy soils in the Isis mill cane supply district and have significant impacts on the profitability and performance of ratoons. This study was undertaken to determine the effect of varieties and nematicide treatment on PPN populations and sugarcane productivity. Four varieties, KQ228$^{\Phi}$, Q183$^{\Phi}$, Q242$^{\Phi}$ and Q245$^{\Phi}$, were grown in large commercial strips that were split for +/– nematicide application in the plant cane crop. The effect of nematicide application on PPN populations was short lived (less than five months), whereas populations of PPN were lowest under Q245$^{\Phi}$ and KQ228$^{\Phi}$ for root-knot and lesion nematodes, respectively. This trial demonstrates that there is a potential to refine the current susceptibility classifications to better enable growers and advisors to select an appropriate variety.

Introduction

Blair and Stirling, (2007) identified that plant-parasitic nematodes (PPN) were a significant productivity constraint in the Australian sugar industry and estimated that their economic impact was $82M at the time. PPN have been well known as a productivity constraint in the Bundaberg region (Bull, 1981). However, work conducted as part of the Sugar Yield Decline Joint Venture identified PPN in all soils growing sugarcane (Blair *et al*., 1999). Lesion nematode (*Pratylenchus zeae*) and root-knot nematodes (*Meloidogyne* spp.) were considered the most important pest species based on abundance and density in the field (Blair *et al*., 1999).

Root-knot nematodes (RKN) are confined to sandy soils (<20% clay) and well-structured clay loams; whereas lesion nematodes were found in 100% of cane paddocks sampled (Blair *et al*., 1999). *Meloidogyne javanica* accounted for 76% of the *Meloidogyne* spp. isolated from southern sugarcane soils. PPN have been implicated as part of the biotic constraint of yield decline (Pankhurst *et al*., 2001, Chandler, 1984). Yield decline is defined as the loss of the productive capacity of soils under long-term sugarcane production (Garside *et al*., 1997).

The traditional method of controlling nematodes in sugarcane farming systems has been through the application of chemical nematicide. Bull (1981) demonstrated productivity responses of 20–60% when nematicides were applied in the Bundaberg district.

However, responses were variable, as nematicide application only controlled nematodes for a short time (49–77 days). However, Kookana *et al*. (1995) demonstrated that nematicides, which are a danger to human health and are toxic to the environment, have the potential to move off-site, highlighting an environmental issue to the industry if broad scale use was to occur.

Breaking the sugarcane monoculture with legumes significantly reduces PPN populations and, at the same time, increases the population of beneficial free living nematodes (FLN) (Stirling *et al*., 2002). In a monoculture, the FLN/PPN ratio is about 2:1, whereas following a legume break the ratio is 20:1. This ratio can be used as a measure of soil health. However, this change in PPN populations is short lived and there is no residual effect of cropping history by the ratoon phase

(Blair and Stirling, 2007, Stirling *et al*., 2002). Stirling *et al.* (2003) suggested that cultural and biological control should form the basis of nematode management strategies.

This experiment was implemented to determine if different sugarcane varieties had differences in susceptibility to PPN in a field situation to enable productivity officers to provide better varietal recommendations for growers known to have paddocks with high PPN populations.

Materials and methods

The site was located on McLennan and Sons property, Wallaville approximately 53 km SW of Bundaberg on the banks of the Burnett River. The soil is classified as a Brown Dermosol (Australian soil classification) and would typically be described as a brown/black loamy soil on Alluvium.

The paddock was planted to peanuts (variety Holt) in October 2011. Nematode sampling at the end of the peanut crop demonstrated no root-knot or lesion nematodes and a total plant-parasitic nematode count of 10 spiral nematodes/200mL soil. The peanut crop was harvested in April 2012 and the paddock was maintained as a clean bare fallow, via cultivation, until the sugarcane trial was planted on 29 August 2012.

The main treatments consisted of four varieties (KQ228$^{\text{(b)}}$, Q183$^{\text{(b)}}$, Q242$^{\text{(b)}}$, and Q245$^{\text{(b)}}$) planted in plots about 200 m long and three rows wide, in a randomised complete block design with three replicates and row width of 1.83 m.

Varieties were randomly allocated in each replicate. On 17 October, 49 days after planting, all plots were split to +/– nematicide. 'Rugby®' 100 G (100 g/kg Cadusafos) was applied at 82 kg/ha through a micro-feed granular applicator that was equipped with finger rakes to immediately incorporate the nematicide. Irrigation was applied that evening to incorporate and activate the chemical.

The site was kept weed free by both mechanical cultivation and application of knock-down and residual herbicides. The site was irrigated via a high pressure travelling irrigator, on a 7–10 day cycle when required. The plant cane crop was fertilised with 140 kg N/ha, 120 kg K/ha and phosphorus (20 kg P/ha) and the ratoons fertilised as per six-easy-steps recommendation (typically 160 kg N/ha and 100 kg K/ha).

Nematode populations were monitored in February and May during the plant and ratoon crop by taking 20 soil sample cores (12 mm diameter) from each treatment to a depth of 150 mm. These cores were bulked and mixed, placed in a plastic bag and samples kept at less than 12^{o} C. The samples were sent to DAF Ecosciences Precinct and nematodes extracted from the soil by placing soil on a Whitehead tray for 96 h (Whitehead and Hemming, 1965). Nematodes were recovered from the resulting solution by sieving twice over a 38 µm sieve.

Cane yields were determined by harvesting 100 m of the centre row of the plots via commercial harvester (John Deere® 3520) and weighed into SRA weigh truck. CCS was determined via a six stalk sub-sample immediately prior to harvest that was analysed at the Isis Central Sugar Mill (for the plant cane crop only).

Data were analysed using Genstat (release 16.1, VSN International) as a split plot design with varieties as the main plots and nematicide application as the sub-plots. Nematode numbers were Log (x+1) transformed prior to statistical analysis. Pair-wise test of means were conducted at P = 0.05 using Fischer's Protected LSD. This paper will focus on two plant-parasitic nematode species of sugarcane, root-knot and lesion nematodes.

Results and discussion

Nematodes

Sampling in February 2013, some three months post nematicide application, demonstrated a significant reduction in the populations of both root -not and lesion nematodes. The untreated plots had 7.67 times and 5.5 times the nematode populations compared with the treated plots for root-knot and lesion nematodes, respectively. However, the chemical control for the root-knot nematodes was short-lived and, by the May sampling, there was no measurable effect on populations with only 23 nematodes/200 mL soil difference between treated and untreated.

There still was a significant reduction in lesion nematode populations in May between the treated and untreated plots, possibly reflecting the longer life cycle of the lesion nematode relative to root-knot nematodes (Table 1).

There was no significant variety effect on nematode populations in February. However, by May there were some obvious varietal effects on nematode populations. There was a highly significant variety effect (P = <0.001) on root-knot populations with RKN populations highest with variety Q183$^{\phi}$ and lowest with variety Q245$^{\phi}$ (Q183$^{\phi a}$ > Q242$^{\phi b}$ > KQ228$^{\phi c}$ > Q245$^{\phi d}$).

A different trend, however, was found with regards to lesion nematode populations with populations of lesion nematode highest with variety Q242$^{\phi}$ and lowest with variety KQ228$^{\phi}$ (Q242$^{\phi a}$ ≥ Q183$^{\phi a}$ > Q245$^{\phi b}$ ≥ KQ228$^{\phi b}$) (P = 0.013). There were no significant variety by nematicide interactions.

Table 1—Effect of varieties and nematicide application on root-knot and lesion nematode populations (per 200 mL soil) in February and May 2013 (plant crop). Values are log (x+1) transformed (values in parenthesis are back-transformed means). Values in columns followed by the same letter are not statistically different (P<0.05).

	February 2013		May 2013	
Variety	Root-knot	Lesion	Root-knot	Lesion
KQ228$^{\phi}$	4.68 (106.5)	1.80 (5.03)	4.77^{c} (117.3)	3.27^{b} (25.4)
Q183$^{\phi}$	4.68 (106.5)	3.67 (38.32)	7.60^{a} (1990.9)	5.01^{a} (149.4)
Q242$^{\phi}$	4.76 (115.8)	4.24 (68.32)	6.50^{b} (661.0)	5.30^{a} (200.1)
Q245$^{\phi}$	2.70 (13.8)	3.22 (24.10)	3.48^{d} (31.6)	3.74^{b} (40.9)
P Value	0.190	0.125	<0.001	0.013
LSD	n.s.	n.s.	0.86	1.15
Nematicide				
No	5.2^{a} (181.0)	4.06^{a} (57.19)	5.63 (277.9)	4.72^{a} (111.7)
Yes	3.2^{b} (23.6)	2.40^{b} (10.40)	5.54 (254.6)	3.94^{b} (50.3)
P Value	0.031	0.002	0.690	0.007
LSD	1.76	0.82	n.s.	0.502
Variety*Nematicide P Value	0.838	0.275	0.182	0.226

The varietal influence on root-knot nematode populations continued into the first ratoon crop. For example, in February the soil in the Q183$^{\phi}$ plots had 10.15 times more root-knot nematodes than Q245$^{\phi}$ (Table 2). The trend was similar in May, but the magnitude of difference had reduced. However, soil in the Q245$^{\phi}$ plots had significantly fewer root-knot nematodes than all other varieties. There was no statistical separation in lesion nematode numbers between the varieties in the first ratoon crop.

There was no evidence of residual nematode control in the plots that had nematicide applied in the plant cane phase, with both root-knot and lesion nematode populations almost identical in the +/– nematicide treatments for the May sampling (Table 2).

Table 2—Effect of varieties and nematicide application on root-knot and lesion nematode populations (per 200mL soil) in February and May 2014 (first ratoon). Values are log (x+1) transformed (values in parenthesis are back-transformed means). Values in columns followed by the same letter are not statistically different (P<0.05).

	February 2014		May 2014	
Variety	Root-knot	Lesion	Root-knot	Lesion
KQ228ⅆ	7.33 [a] (1,528)	4.50 (88.9)	7.01 [a] (1,107)	5.24 (187)
Q183ⅆ	8.22 [a] (3,717)	4.42 (82.5)	7.52 [a] (1,845)	5.38 (216)
Q242ⅆ	7.99 [a] (2,941)	5.05 (155.3)	6.99 [a] (1,081)	5.44 (228)
Q245ⅆ	5.91 [b] (366)	4.96 (141.7)	5.79 [b] (326)	5.73 (306)
P Value	0.026	0.873	0.008	0.561
LSD	1.42	n.s.	0.86	n.s.
Nematicide				
No	7.38 (181.0)	4.83 (124.7)	6.84 (929)	5.44 (229)
Yes	7.34 (23.6)	4.63 (101.9)	6.82 (913)	5.45 (232)
P Value	0.861	0.557	0.934	0.970
LSD	n.s.	n.s.	n.s.	n.s.
Variety*Nematicide P Value	0.908	0.095	0.487	0.378

The varietal effect on root-knot nematode populations in the soil continued into the second ratoon where Q183ⅆ hosted significantly more (P<0.05) RKN than Q245ⅆ, with 2 757 and 481 nematodes/200 mL, respectively. By the second ratoon, KQ228ⅆ hosted significantly fewer lesion nematodes than all other varieties in the trial. As with the first ratoon, there was no evidence of nematicide application effecting root-knot or lesion nematode populations (Table 3).

Table 3—Effect of varieties and nematicide application on root-knot and lesion nematode populations (per 200 mL soil) in February 2015 (second ratoon). Values are log (x+1) transformed (values in parenthesis are back-transformed means). Values in columns followed by the same letter are not statistically different (P<0.05).

	February 2015	
Variety	Root-knot	Lesion
KQ228ⅆ	7.05 [ab] (1,153)	2.90 [b] (17.1)
Q183ⅆ	7.92 [a] (2,757)	5.01 [a] (148.2)
Q242ⅆ	7.15 [ab] (1,274)	5.41 [a] (223.1)
Q245ⅆ	6.18 [b] (481)	5.24 [a] (188.0)
P Value	0.031	0.010
LSD	1.01	1.29
Nematicide		
No	7.07 (1,170)	4.34 (75.9)
Yes	7.09 (1,193)	4.94 (138.2)
P Value	0.917	0.144
LSD	n.s.	n.s.
Variety*Nematicide P Value	0.424	0.530

The February sampling of the third ratoon crop demonstrated a significant variety by nematicide application interaction. The addition of nematicide significantly reduced the lesion nematode populations in the Q183$^{\phi}$ plots, whereas the addition of nematicide increased lesion nematode population in the Q242$^{\phi}$ plots (Figure 1).

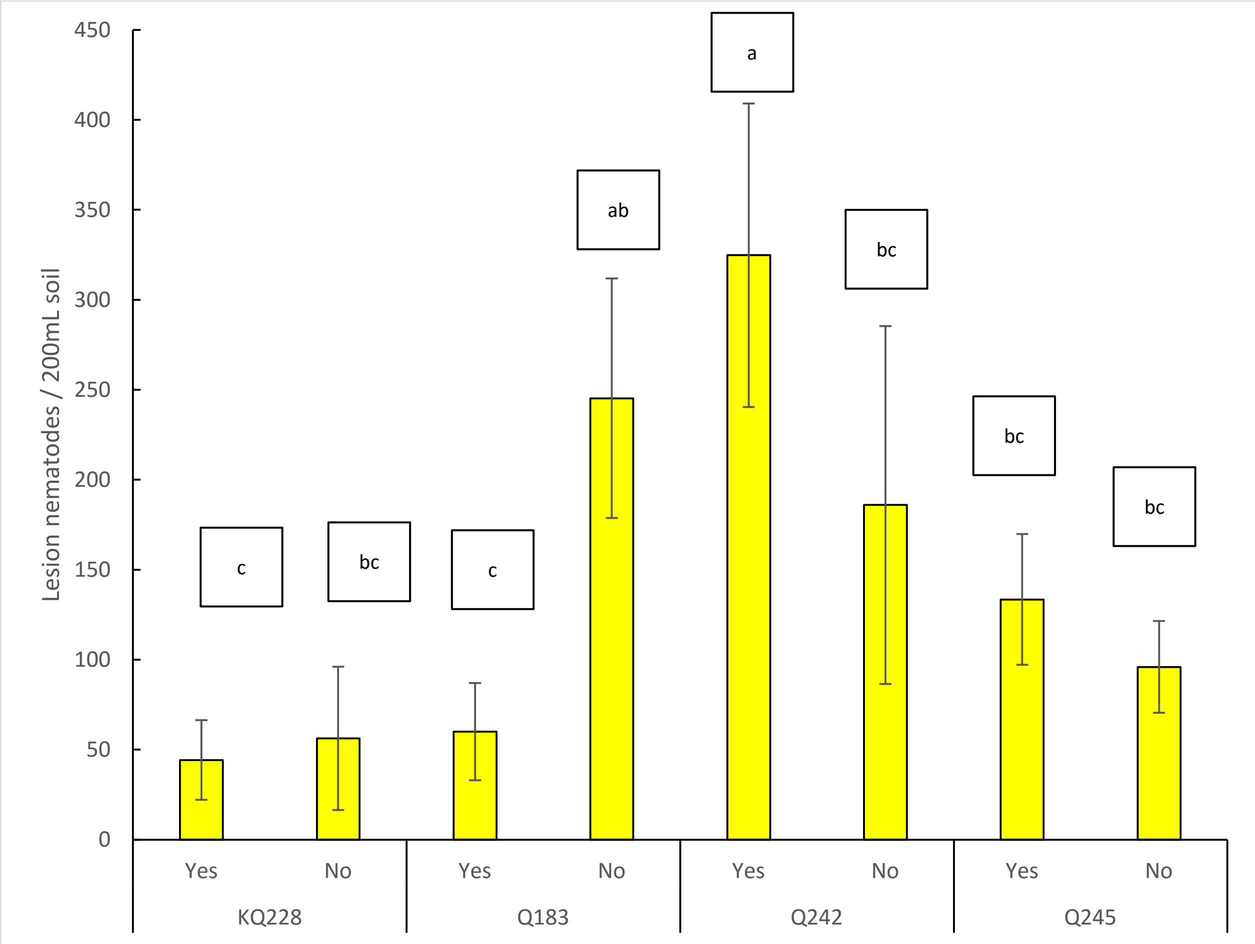

Fig. 1—Varietal by historic nematicide application on lesion nematode populations in February during the third ratoon (R3) crop.

This interaction is difficult to explain as the interaction was no longer evident in the May sampling (Table 4). The interaction was not evident in sugarcane production where the Q183$^{\phi}$ plots with nematicide (which reduced nematode populations compared with the untreated) actually yielded 7 t/ha less than the untreated (data not shown).

Similarly, the yield of Q242$^{\phi}$ plus nematicide, which had the higher lesion nematode counts, yielded 7.3 t/ha more than the untreated plots. Interestingly, the February sampling also demonstrated significantly more root-knot nematodes in the treated plots relative to the untreated; again, this was not evident in the May sampling.

There were highly significantly fewer root-knot nematodes supported in the soil of the Q245$^{\phi}$ plots compared with the other varieties evaluated in 2016, with Q183$^{\phi}$ hosting 19.5 times the number of nematodes relative to Q245$^{\phi}$ in the May sampling. Variety KQ228$^{\phi}$ hosted significantly fewer lesion nematodes compared with Q245$^{\phi}$ and Q242$^{\phi}$ (Table 4).

Soil sampling in the fourth ratoon again highlighted the fact that variety Q245$^{\phi}$ hosted significantly fewer root-knot nematodes than the other varieties evaluated in this field trial.

There was no evidence of the nematicide that was applied in the plant cane phase having any impact on populations of root-knot or lesion nematodes at the end of the crop cycle (Table 5).

Table 4—Effect of varieties and nematicide application on root-knot and lesion nematode populations (per 200mL soil) in February and May 2016 (third ratoon). Values are log (x+1) transformed (values in parenthesis are back-transformed means). Values in columns followed by the same letter are not statistically different (P<0.05).

	February 2016		May 2016	
Variety	Root-knot	Lesion	Root-knot	Lesion
KQ228$^{\phi}$	7.06 ^{a} (1,158)	3.12 (21.6)	6.93 ^{a} (1,019)	3.80 ^{c} (43.6)
Q183$^{\phi}$	7.68 ^{a} (2,154)	4.67 (105.9)	7.57 ^{a} (1,934)	4.42 ^{bc} (82.2)
Q242$^{\phi}$	7.23 ^{a} (1,382)	5.30 (198.4)	6.95 ^{a} (1,038)	5.59 ^{a} (256.8)
Q245$^{\phi}$	5.57 ^{b} (261)	4.67 (105.2)	4.60 ^{b} (99)	4.68 ^{b} (106.7)
P Value	0.003	0.223	<0.001	0.009
LSD	0.794	n.s.	0.86	0.809
Nematicide				
No	6.60 ^{b} (738)	4.57 (95.3)	6.39 (592.5)	4.63 (111.7)
Yes	7.16 ^{a} (1,286)	4.31 (73.3)	6.64 (761.3)	4.61 (50.3)
P Value	0.030	0.321	0.417	0.903
LSD	0.487	n.s.	n.s.	n.s.
Variety*Nematicide P Value	0.357	0.041	0.406	0.648

Table 5—Effect of varieties and nematicide application on root-knot and lesion nematode populations (per 200mL soil) in February 2017 (fourth ratoon). Values are log (x+1) transformed (values in parenthesis are back-transformed means). Values in columns followed by the same letter are not statistically different (P>0.05).

	February 2017	
Variety	Root-knot	Lesion
KQ228$^{\phi}$	7.01 ^{a} (1,104)	3.56 (34.1)
Q183$^{\phi}$	7.49 ^{a} (1,794)	4.49 (88.6)
Q242$^{\phi}$	7.38 ^{a} (1,604)	3.64 (37.3)
Q245$^{\phi}$	6.23 ^{b} (504)	4.82 (122.9)
P Value	0.015	0.262
LSD	0.695	n.s.
Nematicide		
No	7.09 (1,200)	3.78 (42.7)
Yes	6.96 (1.055)	4.48 (87.3)
P Value	0.738	0.180
LSD	n.s.	n.s.
Variety*Nematicide P Value	0.508	0.182

The consistent trend of Q245$^{\phi}$ being a 'less susceptible' host of root-knot nematode throughout the cane cycle is highlighted in Figure 2. This graph also highlights the rapid development in root-knot nematode numbers early in the crop cycle.

Stabilisation in numbers in the ratoon could possibly be due to some biological suppression driven by the green cane trash blanket.

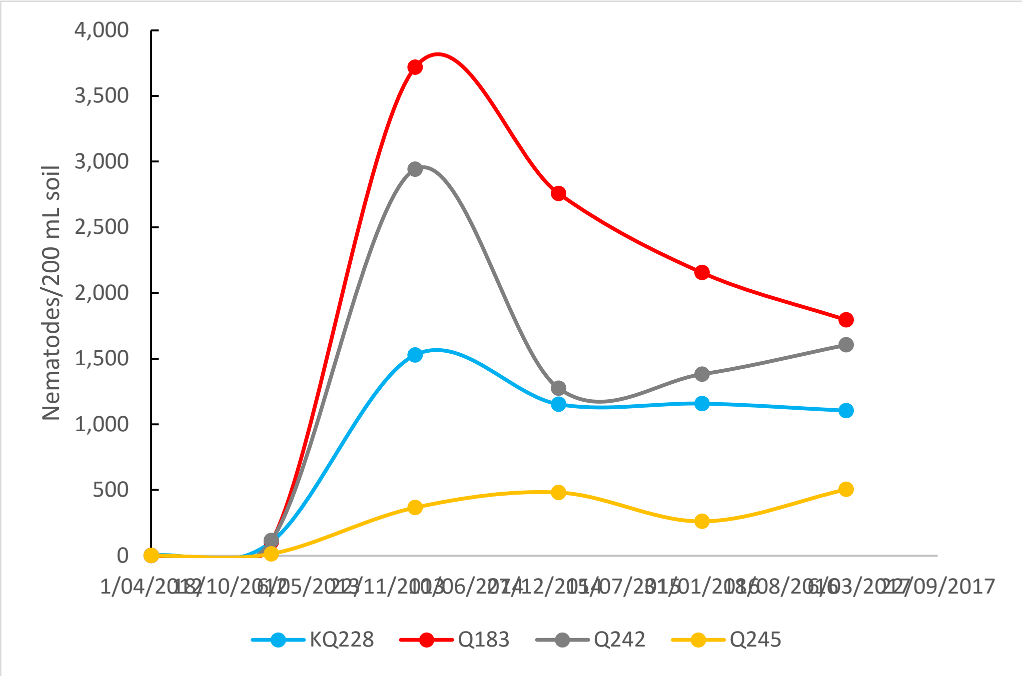

Fig. 2—Varietal effect on root-knot nematode populations through a crop cycle.

Varietal effect on lesion nematode populations throughout the sugarcane crop cycle is less evident than that on root-knot nematode populations; however, KQ228$^{\phi}$ typically ranks with the lowest populations (Figure 3). Interestingly, populations of lesion nematodes appear to 'peak' in ratoons later than that displayed for root-knot nematodes.

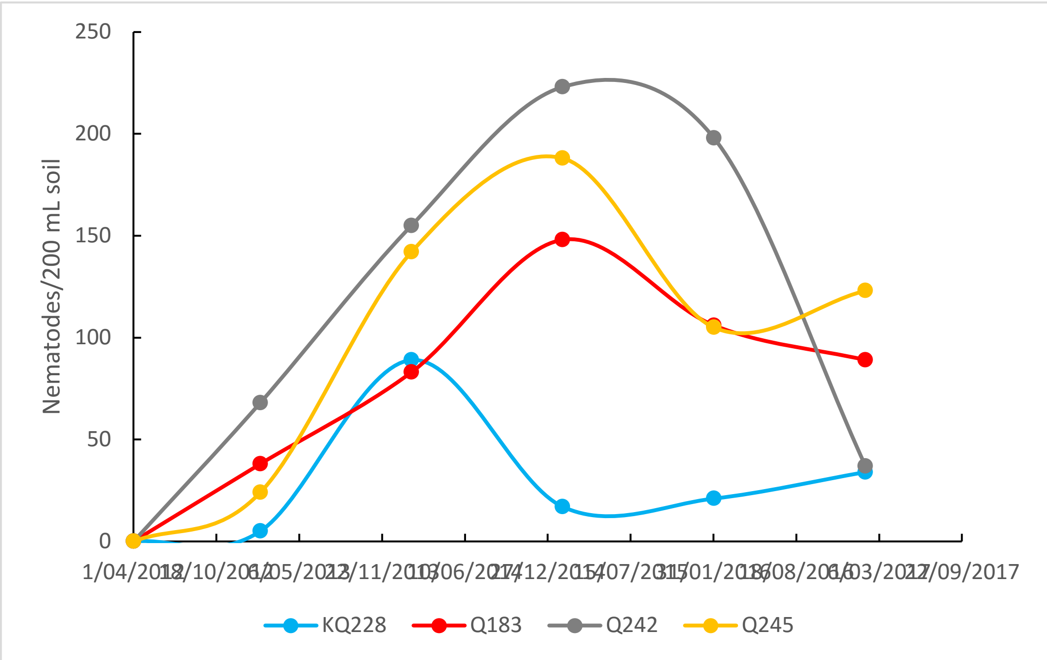

Fig. 3—Varietal effect on lesion nematode populations through a crop cycle.

Sugarcane productivity

There was a significant variety effect on sugarcane productivity in the plant cane crop, with KQ228$^{\phi a}$ ≥ Q245$^{\phi a}$ ≥ Q242$^{\phi ab}$ ≥ Q183$^{\phi b}$. While there was no significant difference in productivity in the subsequent ratoon crops (Figure 4) the productivity of Q245$^{\phi}$ trended to perform better in three of the four ratoon crops.

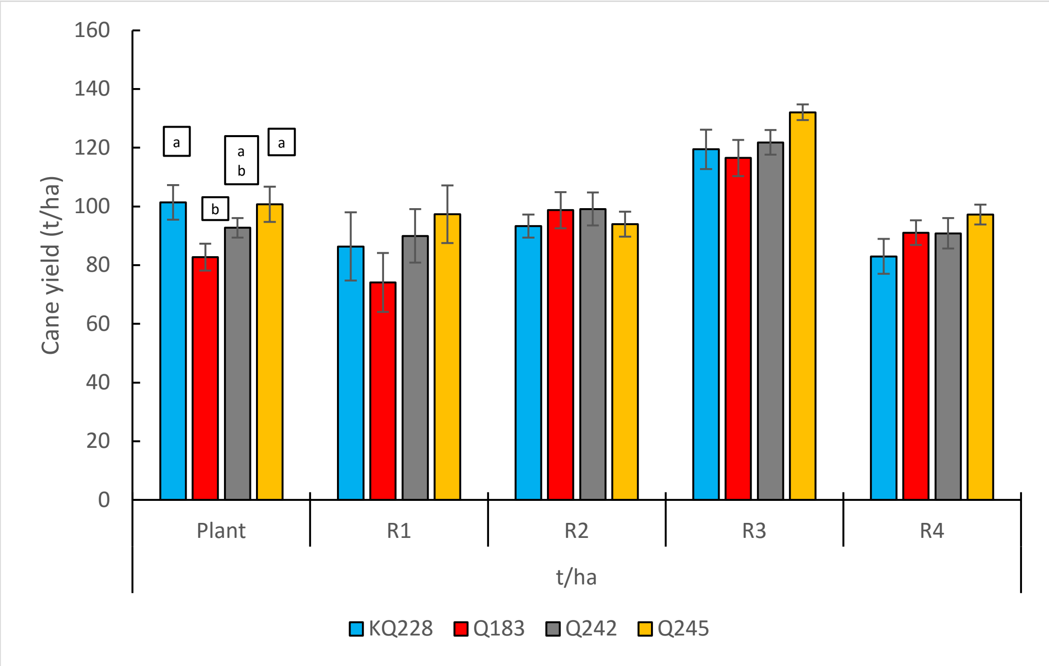

Fig. 4—Varietal effect on sugarcane productivity. Error bars are +/– standard error of treatment mean.

There was a significant correlation (P=0.027) between the population of root-knot nematodes for the May 2013 sampling and sugarcane productivity in the plant cane crop. However, the R^2 value is quite low (Figure 5).

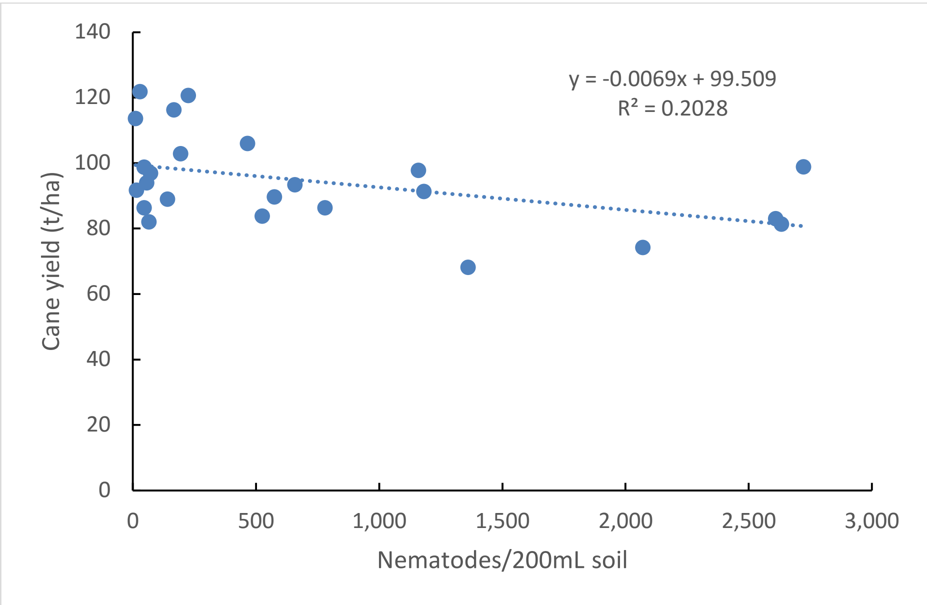

Fig. 5—Correlation between plant cane yield (2013) and root-knot nematode populations in May 2013.

The application of nematicide early in the development of the plant cane crop had no effect on the plant cane, R1, R3, R4 or cumulative sugarcane productivity. However, there was a significant response in productivity of the R2 crop (Table 6).

This response to nematicide application is difficult to explain as there was no effect of the nematicide application on nematode populations during the crop growth phase of the second ratoon (Table 3).

Table 6—Effect of varieties and nematicide application on sugarcane productivity (t/ha). Values in columns followed by the same letter are not statistically different (P=0.05).

Variety	Plant cane	R1 2014	R2 2015	R3 2016	R4 2017	∑ Cane
KQ228[Φ]	101.4 ^{a}	86.4	93.3	119.4	83.0	483
Q183[Φ]	82.7 ^{b}	74.1	98.7	116.5	91.0	463
Q242[Φ]	92.7 ^{ab}	90.0	99.1	121.8	90.8	494
Q245[Φ]	100.7 ^{a}	97.3	94.0	132.0	97.2	521
P Value	0.028	0.403	0.831	0.134	0.087	0.214
LSD	12.1	n.s.	n.s.	n.s.	n.s.	n.s.
Nematicide						
No	92.6	88.5	91.2 ^{b}	121.6	90.6	484
Yes	96.2	85.4	101.3 ^{a}	123.3	90.4	497
P Value	0.547	0.795	0.046	0.772	0.953	0.582
LSD	n.s.	n.s.	9.84	n.s.	n.s.	n.s.
Variety*Nematicide	0.966	0.991	0.829	0.815	0.282	0.995

Conclusions

This field trial highlights the limited effects that nematicides have on reducing the numbers of plant-parasitic nematodes in sugarcane fields. Growers and advisors should not view nematicides as a 'cure all' for paddocks that have had a history of high PPN numbers. Nematicides have high mammalian toxicity, have the potential to contaminate ground water (Kookana *et al*., 1995) and are costly to apply.

Interrogation of the QCANESelect ™ sugarcane variety selection tool identifies all of the varieties tested in this experiment as 'susceptible' to both root-knot and lesion nematodes. Under the strictest definition of 'susceptibility', this is true, as susceptible means that the variety is capable of supporting nematode reproduction.

The authors feel that there is the potential to revise the classifications, as variety Q245[Φ] hosted significantly fewer root-knot nematodes consistently when compared with Q183[Φ] (on some occasions there were 10 fold differences in populations), yet they are all classified similarly. More trials may need to be done to confirm the findings of this experiment as this is only one field trial

A refinement of this scale will enable producers and advisors to make better management decisions in their quest to limit the impact of nematode pressure in the sugarcane farming system.

Acknowledgements

This project was funded by SRDC/SRA Grower Group Innovation Project GPP071 'Strategies to limit the impact of nematode pressure on sugarcane productivity in the Isis'. The successful conduct of this trial would not have been possible without the cooperating producer Peter McLennan. We thank the SRA plant breeding team for providing the 'weigh truck' and FMC Australasia Pty Ltd for the supply of the nematicide.

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