IMPACT OF NEMATODES ON SUGARCANE AND THE BENEFIT OF TOLERANT VARIETIES

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Abstract

The importance of growing sugarcane varieties that minimise losses from nematodes is linked to the effect that the nematodes have on the cane. Revised estimates of crop loss from nematodes in South Africa indicate a reduction in yield equivalent to more than 1.6 million tons cane per annum. The most pathogenic species on sugarcane, *Meloidogyne javanica*, is restricted to very sandy soils. The other pathogenic and much more widespread nematodes are *Pratylenchus zeae*, *Xiphinema elongatum* and species of *Paratrichodorus*. The varieties generally tolerant of these nematodes can be identified by their smaller response to treatment with nematicide. The contribution that tolerant varieties make in minimising losses from nematodes was quantified by comparing their yield with susceptible varieties in six field trials conducted on sandy soil in three regions of the sugar industry, with between three and six crops per trial. Where a nematicide was not used, growing a tolerant variety increased yields by between 25 and 124% (average 83%) over that of a susceptible variety. The benefit was broadly equivalent to the increased yield achieved by treating the susceptible variety with a nematicide. In the six trials this represented an average increase of 34 t cane/ha. It is also shown that nematode tolerant varieties can sustain yields over time through the continued production of high yielding ratoon crops.

Keywords: sugarcane, yield loss, plant parasitic nematodes, varieties

Introduction

Unlike many plant diseases, the problem from plant feeding nematodes comes from the populations in the soil within the field. Movement of nematodes between fields is of little or no consequence in the short term. The number and species of nematodes present in the soil will depend on factors that include the history of the land (forest, grassland, etc), previous and current cropping history and soil type. It is self-evident that the plant feeding nematode fauna in the soil represent those species that are able to feed on the plants currently growing, or those that have recently been grown, in the soil.

At low numbers most plant feeding nematodes have little deleterious effect on plants; indeed, they may even have a stimulatory effect on root growth (Wallace, 1973). Nematodes become a concern to the farmer when the number feeding on the roots exceeds a certain threshold, above which the plant is unable to grow normally. This threshold varies according to the species of nematode, the variety or cultivar of the crop plant, the age of the crop and, according to a wide range of environmental conditions including soil type, soil moisture, presence or absence of other pathogens and presence or absence of beneficial organisms (Barker *et al*., 1985; Luc *et al*., 1990). From the results of numerous field trials in sugarcane, there is little doubt that, for most of the time in the South African sugar industry, the thresholds of the various nematode species are exceeded and damage does occur. The loss in yield as a result of this damage was reported to be more than 720 000 tons cane per year in an area of just over 89 000 hectares (Spaull, 1995).

This figure was derived from field trials, both conventional nematicide trials and trials specifically designed to measure yield loss from nematodes. The soils in these trials were predominantly Recent sands and soils derived from Natal Group sandstone (previously Table Mountain sandstone). The estimate did not include losses from nematodes in alluvial soils or in soils derived from Granite, Dwyka tillite and Vryheid sediments. Almost two-thirds of the soils in the sugar industry are sands, loamy sands, sandy loams and sandy clay loams (Anon, 1999). All these are soils in which nematodes are known to reduce yield of cane (Cadet and Merny 1978; Spaull, 1995; Stirling *et al*., 1999). A more accurate crop loss estimate can be obtained by including estimates for all the sandy soils, together with the most recent data on hectares harvested for milling (Anon, 2002a).

In South Africa, the roots of sugarcane are fed upon by more than 90 species of nematodes. The most common and those causing the most damage are *Meloidogyne javanica*, *Pratylenchus zeae*, *Xiphinema elongatum* and two or three species of *Paratrichodorus*. Control of these nematodes is necessary to ensure sustainable production. Chemical control is used to good effect on the sandier soils, but is not cost effective on the better soils. Growing plants that are resistant to nematodes is an ideal method of sustaining yields (Cook and Evans, 1987). However, finding combined resistance to the complex of five or six species associated with sugarcane seems unlikely (Luc and Reversat, 1985). At present, varieties are selected according to their performance in different environments, and their reaction to diseases and the stalk borer *Eldana saccharina* (Lepidoptera: Pyralidae). No regard is paid to nematodes, but by choosing the best varieties some random selection of nematode tolerance has occurred. This is evidenced by data from field trials that show that certain varieties of sugarcane are more tolerant of nematodes than others (Moberly and Clowes, 1981; McArthur and Spaull, 1995: Cadet and Spaull, 2003).

In this paper the previous estimate of crop loss in sugarcane is amended to include all the soils where nematode damage can occur, and trial data is reviewed to investigate the benefit derived from growing varieties that are tolerant of nematodes. The more nematode tolerant varieties are identified by their smaller response to treatment with a nematicide and by their higher yields achieved in situations where nematodes are a particular problem.

Materials and Methods

Effect of nematodes on sugarcane production

The estimate of crop loss from nematodes, as given by Spaull (1995) for cane growing on the Recent sands and soils derived from Natal Group sandstone, Middle Ecca sandstone and Swaziland Basic Rock, is amended by including all the other soil parent materials with soil forms classed as sands, loamy sands, sandy loams or sandy clay loams. These are the alluvial soils and soils derived from Granite, Dwyka tillite and Vryheid sediments (Anon, 1999). It is assumed that, together, the sandy soils represent 60% of the soils in the sugar industry (Anon, 1999). The crop loss calculation was made based on there being 329 591 hectares of sugarcane harvested for milling during the 2001/2002 season, and that the cane was valued at R160.23 per ton (Anon, 2002a).

Short and long term benefits from growing nematode tolerant varieties

The benefit of tolerant varieties was measured by comparing the performance of tolerant and susceptible varieties in six conventional variety x nematicide trials conducted on sandy soils in three regions of the sugar industry (Table 1). The trials included the plant crop and the following two, four or five ratoon crops. In each trial, half of the plots of each variety were treated with aldicarb (Temik 15G) at 3 kg/ha, and half were left untreated to act as controls. The aldicarb was applied in the furrow at planting or, in the ratoons, over the row within six weeks of harvesting the previous crop.

Table 1. Summary of trials.

Locality	KwaZulu-Natal Midlands		KwaZulu-Natal North Coast		Mpumalanga	
Trial	Klipp-1	Klipp-2	LM-1	LM-2	Potgieter-1	Potgieter-2
Varieties	N12 N17 N21	N12 N16 N17 N21	NCo376 N12 N16 N17 N23 N24	N8 N12 N16 N19 N21 N27	N14 N19 N23 N25 N26 N28 N30 N32	N14 N19 N23 N25 N26 N28 N30 N32
Soil clay content	6.1%	6.0%	7.0%	6.1%	6.3%	6.4%
Rain/irrigated	Rainfed	Rainfed	Rainfed	Rainfed	Irrigated	Irrigated
No. crops	3	3	6	5	3	3
No. replicates	5	5	6	6	6	6
No. and length of rows	5 x 10 m	5 x 10 m	6 x 8 m	5 x 10 m	5 x 8 m	5 x 8 m
Cutting cycle (months)	24	20 – 23	12 – 13	12 – 13	11 – 12	11 – 12

Results and Discussion

Effect of nematodes on sugarcane production: amended crop loss figures

If 60% of the soils in the sugar industry have a sandy texture and 329 591 hectares of sugarcane were harvested for milling in the 2001/2002 season (Anon, 2002a), then the total area of sandy soils harvested was:

$$0.6 \times 329\,591 = 197\,754 \text{ hectares.}$$

If crop loss due to nematodes on 89 750 hectares was estimated to be 727 879 tons cane (Spaull, 1995), then loss in yield on 197 754 hectares is:

$$727\,879 \times 197\,754 \div 89\,750 = 1\,603\,799 \text{ tons cane.}$$

If cane is valued at R160.23 per ton (Anon, 2002a) this is equivalent to more than R256 million and represents 7.6% of annual production. Based on a questionnaire completed by 65 respondents from around the world, the average annual loss of sugarcane due to nematodes was estimated to be 15.3% (Sasser and Freckman, 1987). This was greater than several other earlier estimates, including one of 0.2% from Australia (Anon, 1986; Spaull and Cadet, 1990). However, more recently Stirling *et al.* (1999) corrected the figure for Australia after conducting specific crop loss trials on a wide range of soils in Queensland. The trials demonstrated an estimated annual loss of production of 9%, equivalent to A$100 million per annum. It is clear that plant feeding nematodes are very important pests, although they usually go unnoticed because the above-ground symptoms of damage are not diagnostic. In fact the cost of plant feeding nematodes to the sugar industry is greater than calculated above. Firstly, root damage by nematodes slows down growth, and thus canopy formation, resulting in additional costs for weed control, and secondly, nematodes reduce the sustainable production of sugarcane by reducing the number of high yielding ratoons (Cadet and Spaull, 2003; and see below). Moreover, as shown below, the method of measuring crop loss is fallible and the figure of more than R256 million for the South African sugar industry is probably an underestimate.

Short term benefits from growing nematode tolerant varieties

Table 2 summarises the performance of the varieties in the six trials. Varieties with the smallest response to treatment with nematicide were assumed to be the more tolerant. These were N12 (two trials), N14 (two trials), NCo376 and N8.

When varieties were rated according to both yield and response to treatment the same four varieties had the best rating, although N25 was similar to N14 on the Potgieter-1 trial. Varieties with poor ratings were N17, N19, N21, N24, N26 and N27 (Table 2). N30 could also be included in this group, based on its poor performance in the Potgieter trials. Except for N24, for which no data are available, and N17, which has a variable reaction (McArthur and Spaull, 1995 and unpublished data), all of these varieties are particularly susceptible to root-knot nematodes, *Meloidogyne* spp. *Meloidogyne* was present in all the trial sites except LM-1. A comparison between the performances of N12 and N16 at the LM-1 and LM-2 sites indicates that *Meloidogyne* is responsible for 30% of the loss in yield, equivalent, in the particular trials, to 15 t cane/ha/annum (Cadet and Spaull, 2003). *Meloidogyne* is a problem only in the very sandy soils of the sugar industry. Evidence suggests that varieties resistant to sugarcane smut (*Ustilago scitaminea*) are susceptible to root-knot nematodes (unpublished data). Clearly this is a particular problem on sandy soils in the northern irrigated areas of Pongola and the Onderberg, where resistance to smut is necessary. Varieties NCo292, NCo376, NCo382, N53/216, CB36-14, N8 and N16 are resistant to one or more species of *Meloidogyne* (Spaull and Cadet, 1990 and unpublished data). Only NCo376 and N16 are still widely grown and they, like other varieties, are more or less susceptible to the other plant parasitic nematode species.

As shown in Table 2, the improvement in yield of the most tolerant variety to that of the most susceptible variety ranged from 25 to 124 %. The average improvement was more than 80%. When the tolerant and susceptible varieties were treated with nematicide there was only a 16% benefit from growing the former. With the exception of the LM-2 and Potgieter-1 trials the yield of the nematicide treated, most susceptible variety in each trial was broadly similar to the yield of the untreated, tolerant variety (Table 2). Averaged over the trials, the yield of the least tolerant varieties was 45 t cane/ha. When treated with nematicide, the yield of these varieties increased to 79 t cane/ha. This is the same as the average yield of the untreated tolerant varieties. Thus, as a first estimate, and based only on the data from the six trials, the benefit of growing a tolerant variety on sandy soils can be approximated to the additional yield derived from using a nematicide on a susceptible variety.

Where a nematicide is used the cane is protected from nematode damage during the few weeks following treatment. However, the normal single treatment at the registered (commercial) rate fails to provide long term control and thus does not negate the need for selecting the right variety. Much improved nematode control can be achieved by repeated application of a nematicide (Stirling *et al*., 1999). Such a procedure provides an estimate of the real effect that nematodes have on cane yield. In a variety x nematicide trial on a sandy soil with a diverse fauna of plant parasitic nematodes at Zinkwazi on the north coast of KwaZulu-Natal, N12 yielded 30% more when treated repeatedly at monthly intervals with aldicarb than when treated once at planting (unpublished data). With the same multiple treatment, the yield of N27 doubled compared with the single treatment. Data is available from only this single trial and there were only three replicates per variety. However, it is worth recording that the percentage improvement in yield of the better variety, N12, for the untreated, treated and repeatedly treated cane fell from 84 to 66 to 9% respectively, compared with the susceptible variety N27. The repeated treatment largely removes the nematode constraint from the performance of the two varieties. It confirms the greater tolerance of N12 to nematodes and demonstrates that N12 is very much the better variety for this particular nematode infested site at Zinkwazi, whether treated with nematicide or not. If substantiated by other trials, the yield response to repeated application of nematicide indicates that the actual crop loss from nematodes is much greater than the R256 million estimated above.

Table 2. Summary of the yields of untreated cane and response to treatment with nematicide of varieties in the six trials.

Trial, no. of crops and variety	Average yield of untreated control (t cane/ha)	Average response to nematicide (t cane/ha)	Average response (%)	Rating (% response / yield of untreated control)	Improvement in yield of the most nematode tolerant variety over that of the most susceptible variety
Klipp-1 (3 crops)					
N12*	97.8	16.1	16	0.2 (1)	**N12 cf N17 93%**
N21	65.3	36.5	56	0.9 (2)	
N17**	50.5	56.0	111	2.2 (3)	
Klipp-2 (3 crops)					
N12*	49.4	17.9	36	0.7 (1)	**N12 cf N21 124%**
N17	29.2	18.4	63	2.2 (2)	
N16	34.3	27.9	81	2.4 (3)	
N21**	22.0	29.4	134	6.1 (4)	
LM-1 (6 crops)					
NCo376*	60.5	12.8	21	0.3 (1)	**NCo376 cf N24 123%**
N12	60.7	15.6	26	0.4 (2)	
N17	53.9	21.3	40	0.7 (3)	
N23	54.3	26.5	49	0.9 (4)	
N16	55.3	34.1	62	1.1 (5)	
N24**	27.1	35.2	130	4.8 (6)	
LM-2 (5 crops)					
N8*	33.1	10.9	33	1.0 (1)	**N8 cf N19 25%**
N16	39.8	32.1	81	2.0 (2)	
N12	39.7	41.2	104	2.6 (3)	
N21	29.7	27.1	91	3.1 (4)	
N27	23.0	22.2	97	4.2 (5)	
N19**	26.4	29.0	110	4.2 (5)	
Potgieter-1 (3 crops)					
N14*	124.1	13.0	10	0.08 (1)	**N14 cf N26 99%**
N25	137.2	15.4	11	0.08 (1)	
N32	128.5	20.1	16	0.12 (2)	
N28	114.7	17.0	15	0.13 (3)	
N23	103.3	19.3	19	0.18 (4)	
N19	92.4	19.5	21	0.23 (5)	
N30	66.8	21.5	32	0.48 (6)	
N26**	62.3	21.8	35	0.56 (7)	
Potgieter-2 (3 crops)					
N14*	103.8	6.9	6	0.06 (1)	**N14 cf N19 31%**
N28	92.1	12.9	14	0.15 (2)	
N25	118.6	21.3	18	0.15 (2)	
N23	84.9	17.9	21	0.25 (3)	
N32	98.2	29.5	30	0.31 (4)	
N26	68.6	16.0	23	0.34 (5)	
N30	71.4	21.2	30	0.42 (6)	
N19**	82.7	33.1	40	0.48 (7)	
Without nematicide treatment: Average yield of most tolerant variety = 78.9 t cane/ha Average yield of least tolerant variety = 45.2 t cane/ha With nematicide treatment: Average yield of most tolerant variety = 91.8 t cane/ha Average yield of least tolerant variety = 79.3 t cane/ha					Average improvement in yield = **83%**

* Most tolerant variety ** Least tolerant variety

Long term benefit from growing nematode tolerant varieties

The data in Table 2 give a measure of tolerance per crop. However, tolerance of some varieties is also expressed over time. In the two long term variety x nematicide trials, LM-1 and LM-2, the time taken for the yield to decline to a threshold of 40 t cane per hectare was estimated from the log regression curve fitted to the yield per crop from the first to fourth or fifth ratoon (Cadet and Spaull, 2003). In both trials there was a considerable difference in sustainable production between the varieties (Table 3). The productivity index (yield x sustainability) of the most tolerant variety in LM-1 (NCo376) was much greater than that of the most susceptible variety (N24). The same was not true at LM-2. As shown by the production index of N12 and N16, the potential of the LM-1 site is much greater than that of LM-2 (Table 3). Cadet and Spaull (2003) deduced that this difference was attributable to the presence of *M. javanica* at LM-2, but not at LM-1. The figures in Table 3 for the LM-1 site demonstrate the long term influence that nematodes can have on sugarcane, and emphasise the importance of growing nematode tolerant varieties in soils where nematodes are a problem. The long term effect of nematodes has not been included in the crop loss estimates.

Table 3. Comparison of the productivity indices, calculated from the average yield of the first five or six crops multiplied by the duration in years before the threshold of 40 t cane/ha is reached, for the LM-1 and LM-2 sites (adapted from Cadet and Spaull, 2003).

Trial, no. of crops and variety	Average yield untreated control (t cane/ha) a	Years before yield falls below 40 t cane/ha b	Productivity index (a x b)
LM-1 (6 crops)			
NCo376*	60.5	9	545
N12	60.7	8	486
N17	53.9	7	377
N23	54.3	8	434
N16	55.3	6	332
N24**	27.1	2	54
LM-2 (5 crops)			
N8*	33.1	2	66
N16	39.8	3	119
N12	39.7	3	119
N21	29.7	2	59
N27	23.0	1	23
N19**	26.4	2	53

* Most tolerant variety ** Least tolerant variety

Concluding Comments

It has been argued (Wallace, 1987) that plants that are tolerant of particular stresses caused by abiotic factors are also tolerant of nematodes that cause the same stresses. In other words, tolerance of nematodes may be a non-specific response because the plant responds to the **effect** of the nematodes' disruptive activities and not to the nematodes *per se*. The most obvious effect of the ectoparasites, *Xiphinema* and *Paratrichodorus* spp, feeding on sugarcane is the stunting of the root system and the consequent water stress that it induces. Indeed, the characteristic symptoms of nematode damage in sugarcane, *viz.* a reduction in the number and length of stalks, an open appearance to the rows as the cane is slow to develop a full canopy of leaves over the interrow and a spikey appearance to the leaves as they curl longitudinally, are all symptoms of drought. It might thus be supposed that sugarcane varieties that are tolerant of moisture stress may also be tolerant of nematodes. However, this is not supported by data for some of the varieties included in the six trials.

Table 4 summarises the reaction of the varieties to water stress, as measured by their growth during periods of drought (Anon, 2002b), and their corresponding tolerance of nematodes (derived from Table 2). Varieties N8 and N12 are tolerant of both nematodes and drought, whereas N24 and N26 are susceptible to both nematodes and drought. In contrast, N27 is tolerant of water stress but susceptible to nematodes, and NCo376 and N14 are tolerant of nematodes but are susceptible to water stress. Part of the reason for the smaller response to nematicide treatment of N14 could be attributed to a degree of resistance to *Meloidogyne*, which were abundant in the Potgieter 1 and 2 sites (unpublished data). Similarly, the anomaly with N27 might be explained by its susceptibility to *Meloidogyne* that were common in the LM-2 site (Cadet and Spaull, 2003). Contrasting relationships between drought tolerance and nematode tolerance have also been reported for potato cultivars (Evans and Haydock, 1990).

Table 4. Varieties grouped according to their reaction to water stress (growth during drought) and their corresponding approximate nematode tolerance ratings listed as in Table 2.

Variety	Reaction of variety to water stress (Anon, 2002b)	Nematode tolerance rating per trial (derived from Table 2) T = Tolerant, Int = Intermediate, S = Susceptible.					
		Klipp-1	Klipp-2	LM-1	LM-2	Potgieter-1	Potgieter-2
N8	Good				T		
N12	Average to good	T	T	T	Int		
N17	Above average	S	Int	Int			
N21	Good	Int	S		Int		
N27	Good				S		
N16	Average		Int	Int	Int		
N23	Moderate			Int		Int	Int
N25	Moderate					T	Int
N30	Moderate					S	S
NCo376	Poor			T			
N14	Poor					T	T
N19	Poor				S	Int	S
N24	Very poor			S			
N26	Poor					S	S
N28	Poor					Int	Int
N32	Poor					Int	S

Under rainfed conditions, N12 was identified as the most tolerant variety in two of the trials and rated second or third in the other two trials where it was tested. This variety encourages the development of large populations of *Helicotylenchus dihystera* and discourages populations of the more pathogenic species, with resultant better yields (unpublished data and Cadet *et al*., 2002). It might be surmised that, with the need for more environmentally benign methods of nematode control, the future could see the selection of such varieties as a routine part of the plant breeding programme, and that varieties *per se* will play an even greater role in minimising crop loss from nematodes.

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