EFFECT OF CERTAIN CULTURAL PRACTICES ON NEMATODE MANAGEMENT IN A SMALL-SCALE FARMING SYSTEM

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Abstract

Field trials were planted on a small-scale grower farm in Amatikulu (under rainfed conditions) and Boschfontein (under irrigation). The treatments tested were organic amendments (bagasse, kraal manure and fly ash) applied around the cane sett at planting, and intercropping between the sugarcane rows with velvet beans (*Mucuna deeringiana*), sweet potatoes (*Ipomoea batatas*), sugarbeans (*Phaseolus limensis*) and peanuts (*Arachis hypogaea*). These treatments were compared with the control and nematicide-treated plots. In the plant crop, intercropping with velvet beans, sweet potatoes and peanuts increased nematode infestation in the sett and shoot roots. Conversely, nematicide and bagasse treatments decreased sett and shoot root infestation. Bagasse, kraal manure and fly ash increased the multiplication of free-living nematodes, which are important in improving overall soil health. The two treatments that resulted in increased yield, relative to the control, were applying nematicide at planting (average increase of 18 and 20% cane and ERC yields respectively) and applying kraal manure below and above the sett at planting (average increase of 21 and 20% cane and ERC yields respectively). Kraal manure is a particularly useful amendment for small-scale farmers as it can be produced on the farm by the grower, has been shown to improve sett root germination and provides nutrients through decomposition. These results show that there are alternative control methods (other than nematicides) available to small-scale farmers to improve their productivity on poor soils.

Keywords: sugarcane, small-scale growers, nematodes, intercropping, organic amendments

Introduction

The largest number of sugarcane growers in South Africa fall into the category of 'small-scale growers' (SSGs) who typically farm on land less than 30 hectares in size (Anon, 2003). These growers tend to have more limited resources (land, equipment, finance) than the larger scale growers (commercial growers, miller-cum-planters). Often the land used by SSGs has low fertility status, high acidity, low organic matter content and low levels of many of the major elements (Eweg, 2004). In addition, due to the predominance of sandy soils, it is envisaged that problems due to plant parasitic nematodes are prevalent. However, the exact extent of this loss in productivity is difficult to quantify due to the lack of resources available to SSGs to manage nematode problems with chemical nematicides.

Conventional methods of combating plant parasitic nematodes include the planting of tolerant varieties, planting in cooler months when the nematode populations are smaller, applying nematicides at planting and after each harvest, and allowing a fallow period between crop cycles (Cadet and Spaull, 2005). However, many of these options are not immediately available to many SSGs, and more innovative strategies are needed to manage their nematode problems.

The International Sugar Organisation in 2001 identified as a priority area for funding the need to, “foster programmes to identify potential for intercropping with sugarcane to achieve income diversification at grower level and to better utilise available land, water and labour resources” (http://www.isosugar.org/home/mediumterm/funding.htm). Farmers in Mauritius (Anon, 1998), India (Saini *et al*, 2002) and Pakistan (Hossain *et al*, 2003) have for many years grown intercrops between their sugarcane. They commonly grow crops such as groundnuts and beans, either for money or for feeding the family. In Egypt, sugarcane intercropped with mung beans resulted in improved soil fertility, with increased levels of N and P in the soil (El-Hafiez *et al*, 2003) and intercropping with potatoes resulted in the best cash value return (Abou-Salama *et al*, 2000). Trials conducted by Parsons (1999, 2003), which investigated intercropping with sugarcane in South Africa, showed the economic potential of growing various intercrops between sugarcane rows. However, in this work no data were presented on the effect of these practices on soil health. It is proposed that intercropping, while improving the sustainability and viability of the sugarcane farming enterprise, could sometimes result in even more deleterious conditions, such as increasing the populations of damaging plant parasitic nematodes when planting a nematode-susceptible intercrop (eg. many vegetables) (Netscher and Sikora, 1990) or increasing the levels of insect pests (Giri and Ray, 2002).

Organic by-products of the sugar milling process (e.g. bagasse, filtercake) have long been known to offer benefit as nutrient sources (Blewett, 1924, 1927; Ingham, 1941; Dymond, 1942). Recent work by Dee *et al.* (2002) showed that these amendments are able to ameliorate soil acidity, provide appreciable amounts of nutrients, improve biological activity and improve the overall organic matter content of the soil. Many of these amendments are produced throughout the milling season, are available in large volumes, and are given free-of-charge to sugarcane growers. The major expense is in the transport and application of these amendments. However, with the continuing increase in inorganic fertiliser costs, alternative methods of applying nutrients to the sugarcane crop are needed. The use of local, on-farm organic sources, such as kraal manure, chicken litter, and green manure from food crops or forage, are other options available to the grower.

The aim of this work was to investigate the effect of selected organic amendments and intercropping treatments on sugarcane growth in a small-scale grower farming environment, with particular attention being paid to the effect of these treatments on plant parasitic and free living nematodes, soil nutritional characteristics, sugarcane growth and yield.

Materials and Methods

Sites

Three trials were planted, one on the farm of Mr Zungu at Dokodweni, Northern Kwazulu-Natal (Zungu trial), and two on the farm of Mr William Mhlongo at Boschfontein Estates, Tonga, Mpumalanga (Boschfontein 1 and 2 trials). The field used for the Zungu trial was too small to plant a conventional randomised block trial. Most of the treatments were applied to 5 m x 40 m strips, perpendicular to the cane row, except the nematicide treatment, which was 13 m long x 12 rows wide. The fields used for the two Boschfontein trials were large enough to plant randomised block trials. Details of the trial size, variety used and planting times are given in Table 1.

Table 1. Detail on the sites of the three trials with information relating to the age of cane at harvest, variety, method of weeding, size of plots, number of treatments and replicates, and time of sampling.

Trial	Zungu	Boschfontein 1	Boschfontein 2
Locality	Dokodweni, Amatikulu	Boschfontein, Tonga	Boschfontein, Tonga
Province	KwaZulu-Natal	Mpumalanga	Mpumalanga
Planted	5 September 2002	4 November 2002	21 May 2003
Harvested (Plant Crop)	21 May 2004	4 November 2003	9 July 2004
Harvested (Ratoon Crop)	-	9 November 2004	-
Age at harvest (months)	20	12 (PC), 12 (1R)	12.5
Variety	N12	N32	N32
Rainfed/Irrigated	Rainfed	Irrigated	Irrigated
Row spacing (m)	1.1	1.3	1.3
Sand:Silt:Clay	92:4:4	86:5:8	88:5:7
N:P:K requirements (kg/ha)	120:60:175	140:40:175 (PC), 200:0:175 (1R)	140:40:175
Weeding	Hand weeding	Hand weeding	Hand weeding
Whole plot size (m^2)	198	65	65
Harvest plot size (m^2)	16.5	39	39
No. of treatments	7	6	5
No. of replicates	6	6	6
Sampling- soil analyses	8 months	5 months	7 months
Sampling- leaf analyses	8 months	5 months	7 months
Sampling- nematodes	1,2,3,6,7,9,10 months	1,2,3,4,5,6,8,10 months	1,2,4,6,8 months
Sampling- germination	21, 42, 63 days	-	-

Treatments

Three organic amendments were used in the trials: bagasse and fly ash, both from the local sugar mill, and kraal manure obtained from nearby cattle enclosures. The high density of the manure suggested that on all three occasions it contained a large amount of soil material. The intercrops investigated were sweet potato (*Ipomoea batatas*) and velvet beans (*Mucuna deeringiana*) (Zungu trial) and sugarbeans (*Phaseolus limensis*) and peanuts (*Arachis hypogaea*) (Boschfontein 1 trial). No intercrops were planted in the Boschfontein 2 trial. These crops were chosen after consultation with the grower. The intercrops were sown at the time of sugarcane planting and harvested 3-4 months later. The velvet bean vines were cut back at four months and the aboveground biomass left on the soil in the inter-row as green manure. The sweet potato vines were also left on the soil surface when the tubers were harvested, between two and four months after planting. The sugarbeans and peanuts were harvested three months after planting, and the aboveground material left on the soil surface to decompose. However, most of the sugarbeans died from a foliar disease before harvest. Details of the treatments, dosage and application procedures are given in Table 2. The nutrient value of the organic amendments applied was calculated from their chemical analysis (Table 3). Only 60% of the calculated amount is believed to be available to the plant. The inorganic fertiliser rates applied to all the plots were calculated from soil chemical analysis and were not adjusted according to the amount of organic amendment applied (Table 1). The granules were applied over the sugarcane setts before covering. Nematicide (Temik®, active ingredient: 150 g/kg aldicarb) was applied in the furrow at planting, and covered immediately. The nematicide was reapplied to the first ratoon crop of Boschfontein 1 and the residual effect of the intercrops and organic amendment treatments were monitored.

Table 2. Detail of the treatments applied, rates and methods of application.

Trial	Treatment No.	Treatment	Dosage/plot row	Dose/ha	Application procedure
Zungu	1	Control	–	–	–
	2	Nematicide	3.3 g Aldicarb	3 kg Aldicarb/ha	On the setts, before covering
	3	Velvet beans	Intercrop	–	2 seeds per hole, every 50 cm (11 holes per 5 m interrow)
	4	Sweet potato	Intercrop	–	1 cutting every 50 cm (11 cuttings per 5 m interrow)
	5	Bagasse	50 dm^3 of bagasse below the sett plus 8 dm^3 of kraal manure and 25 dm^3 of bagasse above the sett	36 t bagasse/ha + 14.5 t kraal manure/ha	Below and above the setts, before covering
	6	Kraal manure	25 dm^3 below the sett and 25 dm^3 above the sett	90 t kraal manure/ha	Below and above the setts, before covering
	7	Fly ash	50 dm^3 below the sett and 25 dm^3 above the sett	82 t fly ash/ha	Below and above the setts, before covering
Boschfontein 1	1	Control	–	–	–
	2	Nematicide	3.9 g Aldicarb	3 kg Aldicarb/ha	On the setts, before covering
	3	Peanuts	Intercrop	–	1 seed per hole, every 15 cm, along both sides of the cane row (130 holes per 10 m interrow)
	4	Sugar beans	Intercrop	–	1 seed per hole, every 10 cm, along the middle of the interrow (100 holes per 10 m interrow)
	5	Bagasse	75 dm^3 of bagasse below the sett and 75 dm^3 of bagasse above the sett with 8 dm^3 kraal manure	30 t bagasse/ha + 6 t kraal manure/ha	Below and above the setts, before covering
	6	Kraal manure	16 dm^3 below the sett and 16 dm^3 above the sett	25 t kraal manure/ha	Below and above the setts, before covering
Boschfontein 2	1	Control	–	–	–
	2	Nematicide	3.9 g Aldicarb	3 kg Aldicarb ha^{-1}	On the setts, before covering
	3	Nematicide (multiple)	35.1 g Aldicarb	27 kg Aldicarb ha-1	On the setts, before covering, applied monthly thereafter
	4	Bagasse	75 dm^3 bagasse below the sett plus 16 dm^3 kraal manure above the sett	15 t bagasse/ha + 12 t kraal manure/ha	Below and above the setts, before covering
	5	Kraal manure	16 dm^3 below the sett and 16 dm^3 above the sett	25 t kraal manure/ha	Below and above the setts, before covering

Table 3. Chemical composition of organic amendments and estimated amounts of nutrients added to plots.

Amendment	% N	% P	% K	% Ca	% Mg	% H_2O	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (kg/ha)	Mg (kg/ha)
Bagasse	0.9	0.7	0.1	0.15	0.06	51	7.8	12.9	0.7	2.4	0.7
Kraal manure	1.3	0.8	0.4	0.37	0.17	18	10.3	6.9	3	3	1.4
Fly ash	2.5	2.1	0.2	2.45	0.53	34	16.5	13.6	1.6	16.1	3.5

Sampling

Samples (soil and roots) were collected at various time intervals (Table 1) for nematode identification and enumeration. Soil samples were also collected for soil chemical and physical analyses. Representative samples of leaves from each plot were taken between five to eight months for assessing nutrient uptake by the sugarcane.

Nematodes were extracted from 200 cm^3 soil samples, and between 1 and 5 g fresh weight of roots with the elutriation and the mist chamber techniques of Seinhorst (1950, 1962). The nematode genera were identified and enumerated under the dissecting microscope. Roots were oven dried and the number of nematodes extracted was adjusted to per gram of dry weight. Between five and eight months after planting, the proportions in the soil of clay, silt, fine, medium and coarse sand, the pH (water) and ppm of P, K, S, Ca, Mg, Al, Mn, Zn and Fe, as well as the percentage of C were analysed (Barnard *et al,* 1990). Concurrently the percentages of N, P, K, S, Ca, Mg and Si (%), and Fe, Zn, Mn and Cu (ppm) in the leaves were determined.

After 20 (Zungu), 12 (Boschfontein 1) and 12.5 months (Boschfontein 2), the trials were harvested. For the Zungu trial, the cane in six sub-plots comprising three rows each 5 m long was harvested. For the two Boschfontein trials, the cane from the three middle rows, each 10 m long, was harvested. The harvested cane stalks from each plot were weighed and the yields converted to t cane/ha. Sucrose content was determined from a representative sub-sample of 12 stalks per plot.

Analysis

Experimental data were subjected to Analysis of Variance with the Instat® software package (GraphPad).

Results

(1) Initial plant growth

Soon after planting, setts of sugarcane from the Zungu trial were collected at three time intervals (Table 1) to assess the effect of treatments on germination and initial plant growth. The treatments were ranked according to their effect on plant growth characteristics. After nine weeks, the nematicide and kraal manure treatments ranked the highest (Table 4). The other treatments were ranked similar to that of the control. The only treatment to be worse than the control was intercropping with sweet potatoes. Data from the Boschfontein 1 trial showed that intercropping with peanuts depressed the number of new shoots by an average of 30%, with no effect on stalk height, for the first 120 days after planting (data not shown).

After this period, the number of shoots increased similar to that of the control, but the stalk heights decreased to end 12% shorter than the control at the end of the crop cycle. Intercropping with beans had no adverse effect on stalk counts or heights. Treatment with a nematicide and application of kraal manure increased stalk numbers by 22 and 8% respectively and stalk heights by 9 and 5% respectively. At the end of the crop cycle, all treatments had on average more stalks than the control treatment (data not shown). Intercropping with peanuts and applying bagasse in the furrow resulted in reduced stalk lengths.

Table 4. Classification of various treatments according to their effect on initial plant growth at the Zungu trial site. Ranked from 1 (best) to 7 (worst).

Amendment	% Germination[1]	No. tillers[2]	SeR-S[3]	SeR+S[4]	ShR[5]	Score[6]	Overall rank[7]
Control	5	4	7	4	3	23	3
Bagasse+KM	3	5	3	6	6	23	3
Fly ash	4	6	4	5	5	24	3
Kraal manure	2	2	2	2	2	10	2
Nematicide	1	1	1	1	1	5	1
Sweet potato	7	7	6	7	7	34	4
Velvet beans	6	3	5	3	4	21	3

[1]Number of shoots/number of nodes per sett
[2]Number of shoots per sett
[3]Number of sett roots *without* newly emerged shoots
[4]Number of sett roots *with* newly emerged shoots
[5]Number of nodes with shoot roots
[6]Sum of rankings from preceding five columns
[7]Overall ranking according to Score obtained

(2) Plant crop yield

(a) Zungu trial
Fly ash, bagasse and intercropping with velvet beans and sweet potatoes all exhibited reduced ERC yields relative to the control (Table 5) (not significant, P=0.26). Application of nematicide and kraal manure produced yields that were 22 and 29% respectively more than the control, although the results were not significant (P=0.15).

(b) Boschfontein 1 trial
Intercropping with sugarbeans had little or no effect on ERC yield (-3%), compared with intercropping with peanuts, which had a depressing effect on yield (-27%) (Table 5). Bagasse had a slight depressing effect on yield (-9%). Kraal manure and nematicide treatments yielded the highest, although this was not significant relative to the control treatment. In the first ratoon crop, plots previously intercropped with sugarbeans, which had no effect on cane yield in the plant crop, now exhibited increases in cane and ERC yields of 20 and 29% respectively over that of the control (not significant). The sugarbeans and peanuts succumbed to bacterial diseases after three months and the yields were not determined.

(c) Boschfontein 2 trial
All of the treatments had a positive effect on cane and ERC yields (Table 5). Contrary to the Boschfontein 1 trial, where bagasse tended to decrease cane yields, in this trial the application of bagasse increased cane and ERC yields by 5 and 0.6 tons/ha respectively. As in the other two trials, kraal manure and nematicide treatment produced the best results. Multiple

treatments with nematicide significantly increased the cane and sucrose yields by 72 and 66% respectively (P<0.05). These results show the potential of this variety (N32) when grown in the absence of nematodes for the duration of the crop cycle.

Table 5. Mean harvest data for four crops from three trial sites.

		Cane (t/ha)	SEM	% Control	ERC (t/ha)	SEM	% Control
Zungu Plant Crop	Fly ash	123	4.37	-3	15.2	0.361	-2
	Bagasse+KM	126	9.10	0	12.9	0.78	-17
	Control	127	7.07	–	15.4	1.242	–
	Velvet Beans	129	9.89	2	13.4	1.246	-13
	Sweet Potato	131	9.52	4	14.8	1.256	-4
	Nematicide	155	23.11	22	17.2	4.084	17
	Kraal Manure	163	13.89	29	19.2	1.792	30
Bosch 1 Plant Crop	Peanut	65	3.27	-21	8.2	0.34	-27
	Bagasse+KM	74	5.82	-9	10.3	0.76	-9
	Sugarbeans	80	4.15	-2	11.0	0.76	-3
	Control	81	6.60	–	11.3	0.81	–
	Kraal Manure	91	7.10	12	12.6	0.86	12
	Nematicide	91	5.27	12	12.7	0.92	12
Bosch 1 1st Ratoon	Control	94	6.53	–	11.7	0.99	–
	(Bagasse+KM)	101	5.16	7	13.8	0.57	16
	(Peanut)	103	5.85	9	13.7	0.89	17
	(Kraal Manure)	108	4.49	15	14.9	0.76	27
	(Sugarbeans)	113	7.42	20	15.2	0.76	29
	Nematicide	115	5.95	22	15.3	1.02	30
Bosch 2 Plant Crop	Control	49	2.31	–	6.1	0.30	–
	Bagasse+KM	54	3.50	10	6.7	0.52	11
	Kraal Manure	59	6.62	21	7.5	0.67	23
	Nematicide	59	4.41	22	7.5	0.75	24
	Multiple nematicide	84*	6.46	72	10.1*	0.52	66

*P<0.05, significantly different from control treatment

(3) Changes in soil fertility

(a) Chemical changes

The soil in the rainfed Zungu trial (average pH 5.66) was markedly more acidic than that in the two irrigated trials (Boschfontein 1 and 2, average pH 7.21) (Table 6). However, the treatment with fly ash ameliorated the soil acidity, significantly increasing the pH from 5.32 (control) to 6.57 (fly ash treatment) (P<0.001). Compared with bagasse and kraal manure, fly ash contained the highest amounts of nitrogen, phosphorous, calcium and magnesium (Table 3). Levels of P, Ca and Mg were greater in the fly ash amended soil six months after application (Table 6). Similarly, plots treated with kraal manure, which had more nutritive value than bagasse and less than fly ash (Table 3), had higher levels of P (at all three trial sites) and higher levels of K, Ca and Mg (at two of the sites) (Table 6). Bagasse contained appreciable amounts of N, P, K, Ca and Mg (Table 3); however, the levels of these elements in the soil were not significantly higher in the amended plots compared with the control plots (Table 6), and there is no evidence that these elements (except perhaps potassium) are made available to the plant (Table 7).

Table 6. Chemical elements in the soil measured five to eight months after planting.

		pH	P	K	S	Ca	Mg	Na	Mn
Zungu	Control	5.32	20	23	11	62	43	13	19
	Nematicide	5.45	21	23	13	38	19	9	12
	Velvet Bean	5.54	21	34	10	51	36	21	16
	Sweet Potato	5.44	19	25	13	62	39	14	18
	Fly ash	6.57	>80	33	12	227	71	54	18
	Kraal Manure	5.68	41	44	15	74	51	15	14
	Bagasse+KM	5.65	20	39	11	67	47	19	19
	Average:	5.66	24	31	12	83	44	21	17
Bosch 1	Control	6.89	23	37	9	268	96	54	54
	Nematicide	7.39	34	29	11	332	106	47	58
	Sugarbeans	7.13	48	36	10	639	106	54	50
	Peanut	7.05	45	33	9	352	103	51	52
	Kraal Manure	7.68	44	51	11	456	193	51	66
	Bagasse+KM	7.21	39	40	10	384	134	49	69
	Average:	7.22	39	38	10	405	123	51	58
Bosch 2	Control	7.31	20	255	6	282	109	62	21
	Nematicide	7.32	43	259	8	233	80	59	17
	Multiple Nemat.	7.15	19	296	10	254	91	66	19
	Kraal Manure	6.96	46	212	10	289	96	67	20
	Bagasse+KM	7.28	35	244	8	290	94	53	16
	Average:	7.20	32	253	8	270	94	61	19

Table 7. Plant nutrition as measured by the composition of chemical elements in the leaves.

		%N	%P	%K	%S	%Ca	%Mg	N/S	%Si
Zungu	Control	2.04	0.19	0.60	0.16	0.27	0.25	12.7	0.67
	Nematicide	1.84	0.17	1.28	0.14	0.20	0.14	13.1	0.55
	Velvet Bean	1.81	0.19	1.00	0.16	0.20	0.19	11.3	0.50
	Sweet Potato	1.91	0.18	0.63	0.16	0.27	0.24	11.9	0.62
	Fly ash	2.03	0.17	0.90	0.19	0.25	0.20	10.6	1.06
	Kraal Manure	1.77	0.18	1.18	0.17	0.23	0.17	10.4	0.59
	Bagasse+KM	1.98	0.18	0.98	0.17	0.24	0.22	11.6	0.66
Bosch 1	Control	2.20	0.17	0.95	0.17	0.31	0.21	13.4	0.92
	Nematicide	2.14	0.17	0.88	0.17	0.32	0.21	12.7	1.02
	Sugarbeans	2.19	0.18	1.01	0.17	0.31	0.20	12.9	1.08
	Peanut	2.25	0.18	1.00	0.17	0.33	0.21	13.2	0.95
	Kraal Manure	2.16	0.18	1.03	0.17	0.32	0.20	12.7	0.89
	Bagasse+KM	2.18	0.18	1.01	0.18	0.32	0.21	12.4	0.94
Bosch 2	Control	1.85	0.21	1.36	0.17	0.37	0.23	11.2	0.87
	Nematicide	1.80	0.21	1.45	0.19	0.35	0.23	9.9	0.89
	Multiple Nemat.	1.82	0.22	1.46	0.24	0.36	0.23	7.8	1.16
	Kraal Manure	1.81	0.22	1.48	0.19	0.36	0.21	9.6	1.00
	Bagasse+KM	1.82	0.21	1.49	0.18	0.36	0.21	10.1	1.07

(b) Biological changes

Adding organic amendment in the furrow at planting increases the amount of organic matter in the soil. This is particularly beneficial to sandy soils inherently low in organic matter. Measurements of percentage labile carbon, representative of the active carbon pool in the soil (van Antwerpen *et al*, 2003) (Figure 1), showed that for both Boschfontein trials, the addition of kraal manure increased the amount of carbon in the soil. This increase was highly significant ($P<0.001$) for the Boschfontein 2 trial. Addition of bagasse did not significantly increase % C. Measurement of the basal respiration rate (indicative of total biological activity in the soil) (Figure 2) revealed that in Boschfontein 1, bagasse increased the biological activity more than did kraal manure ($P=0.0045$).

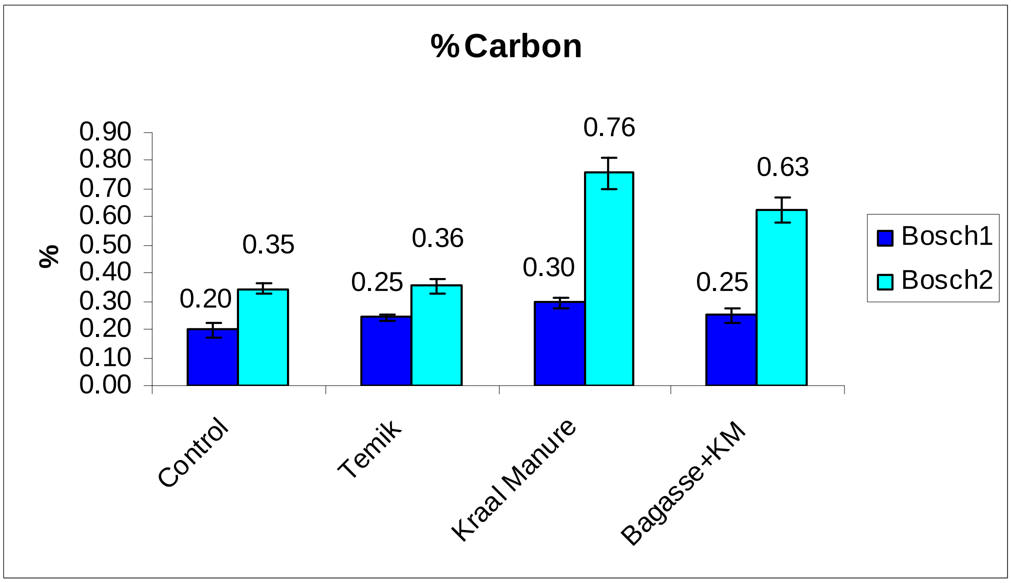

Figure 1. Effect of treatment on labile carbon content of the soil.

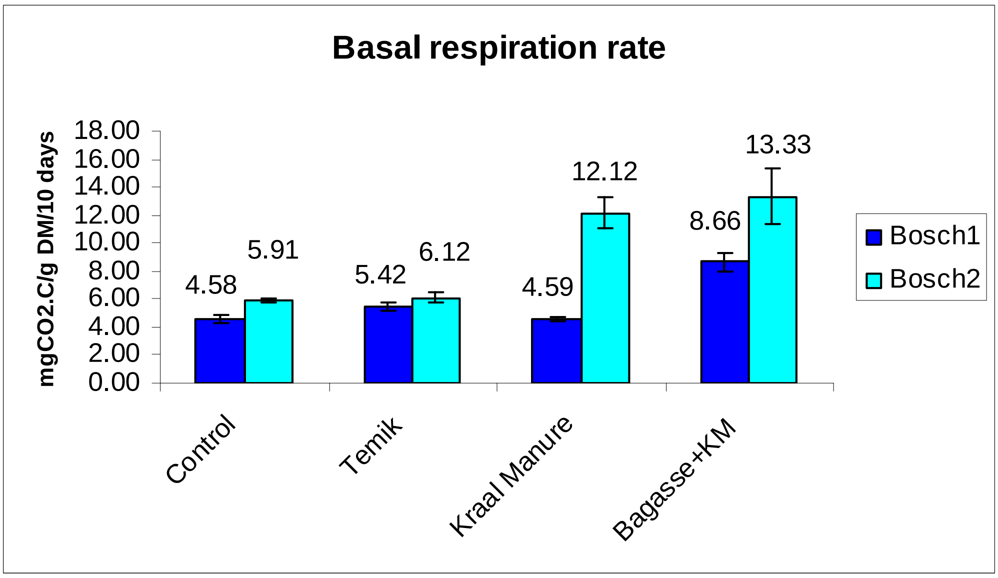

Figure 2. Effect of treatment on basal respiration rate of the soil.

(c) Nematode changes - free living (FL) nematodes

The application of kraal manure and bagasse increased the free-living (FL) nematode numbers compared with those of the control in the Zungu and Boschfontein 2 trials (Figures 3a and 3c). Fly ash appears to have had no effect in increasing FL numbers (Figure 3a). Applying a nematicide resulted in reduced FL nematode populations. Conversely, intercropping had no apparent effects on increasing FL numbers early in the crop cycle, although it is apparent (Figures 3d-e) that later in the cycle there were substantial increases in FL numbers.

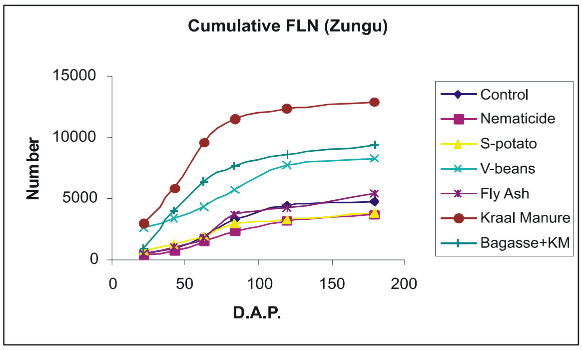

Figure 3a. Acculumulation of free living nematodes at Zungu.

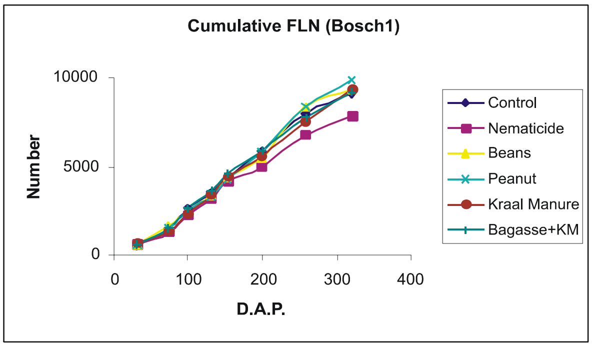

Figure 3b. Accumulation of free living nematodes at Boschfontein 1.

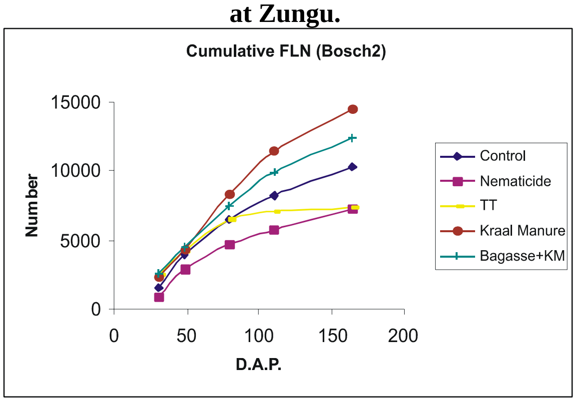

Figure 3c. Accumulation of free living nematodes at Boschfontein 2.

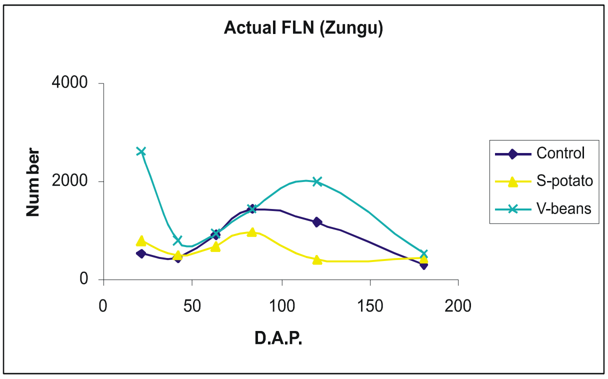

Figure 3d. Number of free living nematodes in soil intercropped with sweet potato and velvet beans at Zungu.

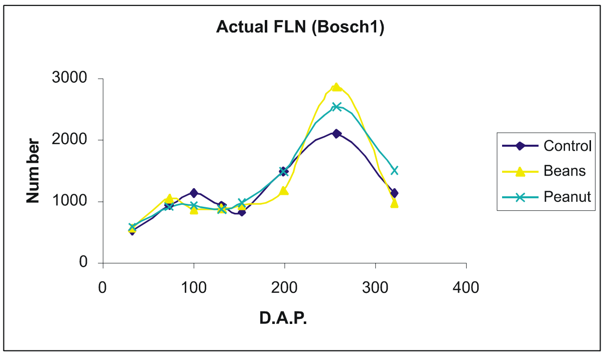

Figure 3e. Number of free living nematodes in soil intercropped with sugarbeans and peanuts at Boschfontein 1.

(d) Nematode changes - plant parasitic nematodes

Soil and root samples were collected from the sugarcane crop at various time intervals during the crop cycle (Table 1). The plant parasitic nematode (PPN) genera most commonly associated with each trial site are listed in Table 8. The presence of these nematodes and the low % clay at all three trial sites, would warrant application of a nematicide under normal conditions.

Table 8. Plant parasitic nematode genera found in >50% of samples analysed.

	Zungu	Boschfontein 1	Boschfontein 2
Soil	*Pratylenchus* *Helicotylenchus* *Meloidogyne* *Xiphinema* *Criconemella* *Scutellonema*	*Pratylenchus* *Helicotylenchus* *Meloidogyne* *Paratrichodorus* *Criconemella* *Scutellonema* *Longidorus*	*Pratylenchus* *Meloidogyne* *Xiphinema* *Paratrichodorus* *Criconemella* *Scutellonema*
Roots	*Pratylenchus* *Meloidogyne*	*Pratylenchus* *Meloidogyne*	*Pratylenchus* *Meloidogyne*

(e) Nematode changes - sett roots

During the first three months after planting, the treatments could be split into three groups according to sett root infestation (Figures 4a-c). Roots of cane intercropped with sweet potato, velvet beans and peanuts were the most infested, followed by roots of cane treated with kraal manure and control cane. The least infested sett roots were found in the plots treated with fly ash, bagasse and nematicide. The only exception to this was the Boschfontein 2 trial, where the single and multiple applications of nematicides showed the greatest increase in sett root infestation and the kraal manure treatment had a depressing effect on sett root invasion. However, this particular trial was planted in the cooler month of May, and the nematode activity was lower during this period. This is shown by the accumulated sett root infestation for the control treatment reaching only 550 nematodes/gram roots 80 days after planting. Much greater numbers were recorded in the Zungu and Boschfontein 1 trials.

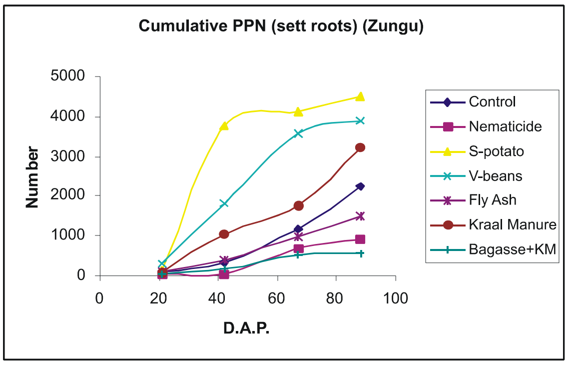

Figure 4a. Sett root infestation at Zungu.

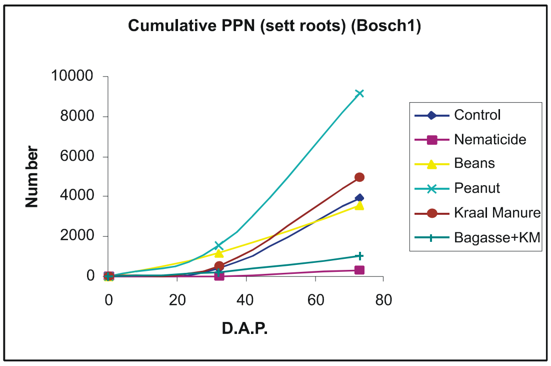

Figure 4b. Sett root infestation at Boschfontein 1.

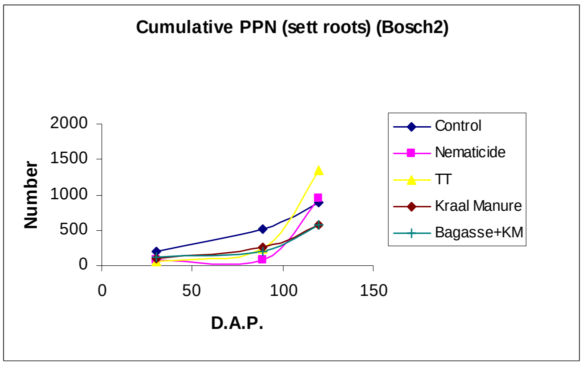

Figure 4c. Sett root infestation at Boschfontein 2.

(f) Nematode changes - shoot roots

In general, the level of infestation of the shoot roots was low for the first 75 days in the Zungu and Boschfontein 1 trials (both planted in warmer months) compared with the first 120 days for the Boschfontein 2 trial (planted in a cooler month). Thereafter, the numbers increased and the effects of the treatments were visible. All the intercropping plots tended to exhibit increased nematode infestation in the shoot roots (Figures 5a-b). This increase was permanent for the sugarbeans and peanuts (Figure 5b), but only temporary for the velvet beans and sweet potatoes (Figure 5a). Nematicide application had a marked depressive effect on shoot root infestation in the Boschfontein 1 trial (P<0.01). Bagasse treatment significantly reduced shoot root infestation in the Zungu and Boschfontein 1 trials (P=0.02 and P<0.01 respectively).

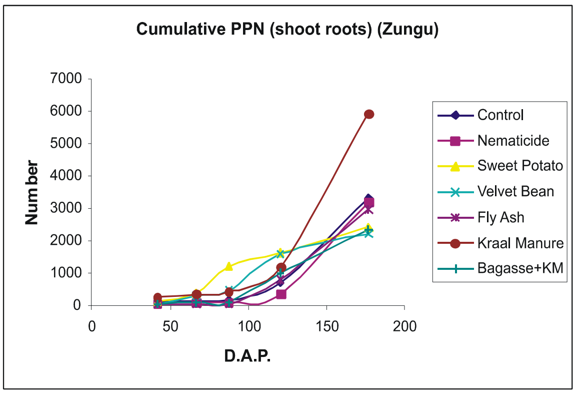

Figure 5a. Shoot root infestation at Zungu.

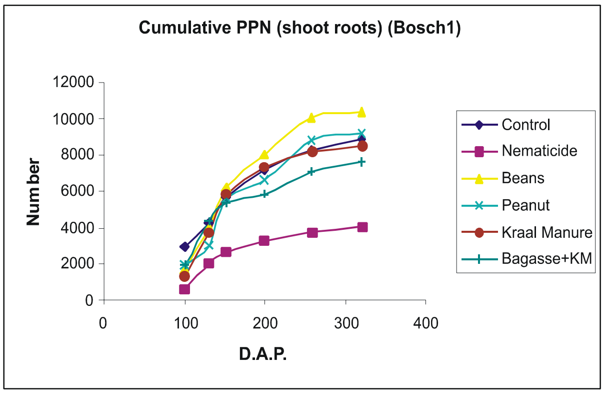

Figure 5b. Shoot root infestation at Boschfontein 1.

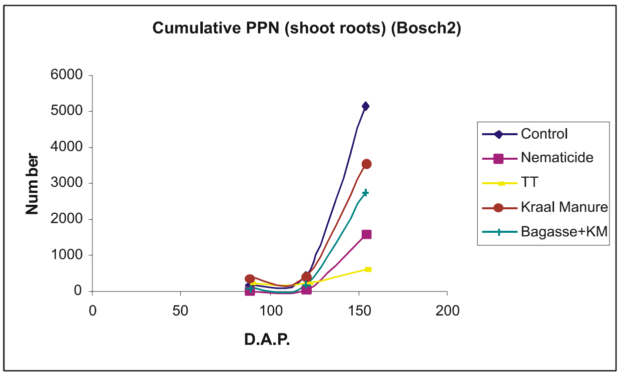

Figure 5c. Shoot root infestation at Boschfontein 2.

(g) Nematode changes - soil

In the Boschfontein 1 trial, for the first 200 days of growth, there were no significant differences between treatments. After this period, however, the plant-parasitic community increased for all treatments, but to a lesser degree for kraal manure and nematicide treatments (Figure 6b). There was a tendency (not significant) for sugarbeans to host more nematodes than other treatments, most probably due to sugarbeans supporting higher numbers of plant parasitic nematodes than peanuts (Figure 6c). At the end of the crop cycle, the nematicide treatment had significantly less nematodes than the control (P<0.05). In the Boschfontein 2 trial (Figure 6d), the nematicide treatments decreased nematode numbers (highly significant, P<0.001). In the Zungu trial (Figure 6a), there were no significant effects of any treatment on nematode numbers.

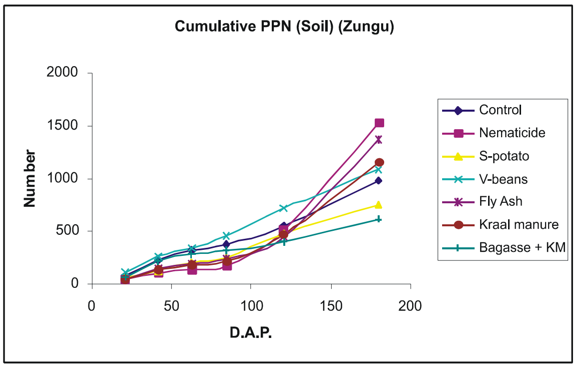

Figure 6a: Nematode infestation in the soil at Zungu.

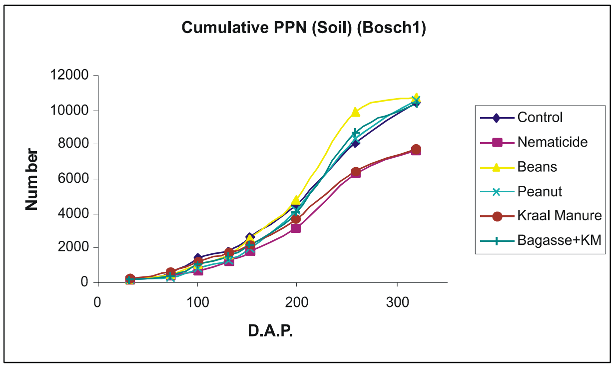

Figure 6b: Nematode infestation in the soil at Boschfontein 1.

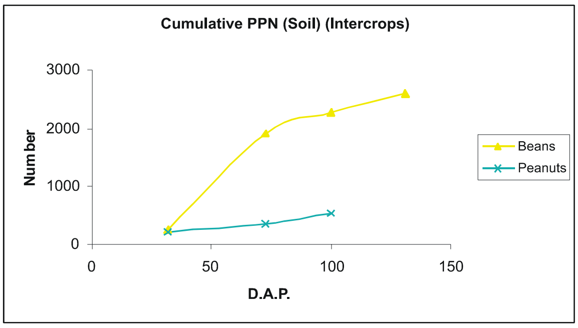

Figure 6c: Nematode infestation in the soil of the intercrops grown adjacent to sugarcane at Boschfontein 1.

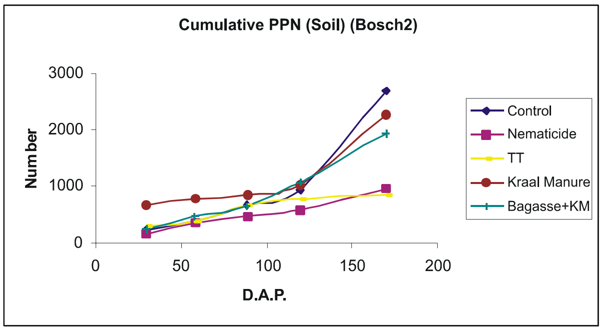

Figure 6d: Nematode infestation in the soil at Boschfontein 2.

Discussion

It is generally accepted that the long term monocropping of sugarcane can lead to soil degradation and a build-up of pests and diseases (Meyer *et al*, 1996). Ways of preventing this scenario could be by planting green manure crops or leaving fields fallow between sugarcane cycles, rotating sugarcane varieties, and timeous and correct applications of fertilisers, herbicides, insecticides and nematicides. However, many SSGs lack the resources to adopt these practices. Data from this work, and work by Parsons (1999, 2003) have shown that intercropping of certain crops between sugarcane rows is possible without compromising cane productivity. From the work presented here, although there were initial effects on cane growth, there was no significant effect on yield at harvest. Sweet potatoes intercropped between the cane yielded ~12.5 tons/ha at harvest. This yield was slightly less than the average yield of 19 tons/ha (ranging from 2.9-34.6 tons/ha) found by Parsons (2003).

Similar work on sandy clay loam soils in Kenya found that intercropping with maize and soybeans, regardless of the planting pattern, significantly decreased sugarcane tillering at the beginning of the cycle. However, yields at harvest were not affected. Intercropping with beans did not affect cane tillering, yield or quality at harvest. Sugarcane yield was also better when intercropped with common beans and soybean (one row) than in pure stand (http://www.kari.org/1999AReport/Sugarcane.htm). In Pakistan, intercropping with berseem and wheat in ratoon crops reduced cane yield by 3 and 9% respectively. However, the overall income per hectare was substantially increased (Solangi *et al*, 1987). Experience from this work has shown that velvet beans, while useful for cattle feed or for improving soil health, can negatively affect the cane if grown for longer than 3-4 months. The residual benefits of growing such a crop and leaving a mulch on the surface after harvesting the intercrop is an increase in free-living (non-plant parasitic) nematodes. These nematodes can be used as indicators of soil health (Gupta and Yeates, 1997) and an increase in FL numbers is often suggestive of increased microbial activity and turnover, which results in increased availability of nutrients to the plant. Intercropping with sweet potatoes and peanuts affected the initial growth and tillering of sugarcane. Perhaps this could have been alleviated by planting these intercrops every alternate row (as suggested by Parsons, 2003), increasing the row spacing, planting these crops in the interrow and not adjacent to the cane row, or reducing the amount of seed sown per interrow. The success of intercropping could also be influenced by the type of sugarcane variety used. A variety such as N12 which takes longer to canopy than, for example N31, may be more favourable for intercropping, as there would be a longer time to grow and harvest the intercrops.

The hypothesis of adding an organic amendment in the furrow at planting is to provide a 'screen' around the planted sett. This is thought to prevent plant parasitic nematodes from entering and damaging the newly formed sett roots. Additional benefits to be gained from the correct organic amendments are provision of a nutrient source, increased soil porosity, increased organic matter content and an increase in soil microbial activity. Results from this work have shown that the choice of organic amendment is important. While kraal manure and bagasse can both be classified as organic amendments, their effects on the cane plant and soil fauna are different. Kraal manure increased the carbon (organic matter) and free-living nematode levels more than bagasse, whereas the bagasse showed a higher microbial activity. Kraal manure response can be explained by an effect on the germination process and the biological control of nematodes. Triggering the germination of the sett roots before nematode invasion will synchronise shoot growth and reduce the detrimental nematode effect. The beneficial effect of bagasse is to destructure the soil and prevent nematodes from attacking the roots. The amount of kraal manure used was not sufficient to provide the same effect. Data from this work showed that nematicide treatment and application of bagasse in the furrow reduced the nematode populations for the duration of the development and establishment of the sett root system. This supports the hypothesis that surrounding the sett with a physical amendment, such as bagasse, physically destructures the soil immediately around the sett, preventing nematodes from attacking the newly emerging sett roots. Although fly ash provided the same protection against sett root damage as bagasse, it had the additional benefits of increasing soil nutrient levels and ameliorating acidity.

Conclusion

Some of the technologies presented in this paper could be adopted by SSGs. Applying kraal manure in the furrow at planting (which would improve germination, increase moisture retention and provide nutrients), and sowing an appropriate intercrop (such as sweet potato or sugarbeans) between every alternate cane row would be an efficient way of utilising limited resources. However, there still remains a lack of knowledge on recommendable intercrops. Whereas the success of sugarcane is based on monocropping, the success of intercropping is based on crop diversity, to avoid punctual overflow of similar products on the market and reduce pest and disease build-up. In the short term, only the economical profit can be commended as advantageous. However, in the long term, this diversity based system will greatly benefit the small-scale grower, particularly in terms of overall improvement in soil quality.

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