THE EFFECTS OF CANE TRASH ON YIELD AND NUTRITION FROM THE LONG-TERM FIELD TRIAL AT MOUNT EDGECOMBE

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Abstract

This paper reports on the yield and nutritional trends over 61 years as affected by various treatments (trashed, burnt with tops either left or removed and all plots either fertilised or not fertilised) of the burning and trashing trial (BT1) at Mount Edgecombe. The overall mean residual yield benefit due to trashing was 9.3 tc/ha/an after 39 crops. The capacity of the Arcadia soil form (Vertisol) to sustain yields without fertiliser was 18 years or 8 crops. The fertilised trashed treatment produced 20 tons trash per hectare (variety N16), which contained about 150 kg N/ha, 20 kg P/ha and 260 kg K/ha. Trash from the green cane harvesting treatment with fertiliser was insufficient to prevent a decrease in soil organic matter. However, soil organic matter loss was greater for treatments where cane was burnt. The N and K released from cane trash contributed to the higher yields from the trashed treatments when compared with the burnt treatments. The fertilised treatments significantly increased soil acidification when compared with the non-fertilised treatments and trash from the green cane treatments also contributed to soil acidity. Only the fertilised treatments, whether trashed or burnt, showed a positive yield response to rainfall.

Keywords: sugarcane, green cane harvesting, burnt, long term trial, yield, nutrition

Introduction

In the South African sugar industry today the emphasis is towards increased productivity (ease of cane removal from the field and greater tonnage per cutter) and mechanisation. In order to accomplish this many more growers are burning rather then trashing their fields before harvest, and this has resulted in reduced returns of organic matter to the soil. Surveys conducted in the South African sugar industry in the nineties by Schroeder *et al*. (1994), Meyer *et al*. (1996) and van Antwerpen and Meyer (1996) have all linked soil acidification and salinisation to reduced soil organic matter. Also in the nineties the sugarcane yield plateau became evident and research projects were initiated to investigate this phenomenon (Meyer *et al*., 1996). Although no single causative factor could be identified it was suggested that a combination of factors were responsible and, of these, organic matter was prominent. The aim of this paper is to summarise the effects that 61 years of trashing as opposed to burning have had on the yield and nutrient trends of the long-term trial (BT1) at the South African Sugar Association Experiment Station (SASEX).

Methods and materials

The BT1 trial site

The burning and trashing trial (BT1) was established at the SASEX in 1939 on a dryland site with a mean annual rainfall of 950 mm. The trial is situated on a Vertisol (Acardia form, Lonehill family; Soil Classification Working Group, 1991) derived from dolerite and containing 57% clay, with a vertic A-horizon about 500 mm deep overlying an unspecified C-horizon. The design of the trial consists of four replications of two main treatments each split into four sub-treatments yielding 32 plots, each with 7 rows, which are 18 m long. The treatments are trashed (T) versus burnt (B) cane and the burnt treatment is subdivided into tops spread (t) and tops removed (to). A further split over all treatments is no fertiliser (Fo) versus applied fertiliser (F). The number of replications is four for the burnt treatments and eight for the trashed treatments. As with most long-term trials the treatments in BT1 have been changed over the years, as shown in Table 1.

Harvesting history

The trial was initially harvested at 24 months of age up to 1966, after which harvesting was changed to between 15 and 20 months. Since 1987 the trial has been harvested annually in spring (see Table 2 for the cycle history and varieties used). The fertiliser mixture used between crops is 5:1:5(46) @ 670 kg/ha which gives 140, 20 and 140 kg N, P and K/ha respectively.

Soil and leaf sampling history

Between June 1945 and June 1998, composite topsoil samples were taken on 22 occasions to a depth of 200 mm from each of the 32 plots. Soil pH was determined in a 1:2.5 soil to water ratio using a glass electrode. Plant available P was determined by extraction with the modified Truog reagent (0.02 $N\,H_2SO_4$) (Du Toit 1962). Exchangeable K, Ca, Mg and Na were extracted with 1 N ammonium acetate (Du Toit 1959) and cations in the extracts were analysed by atomic absorption spectrophotometry. Organic C was determined by a dichromate wet oxidation procedure (modified Walkley and Black 1934).

Leaf samples were taken between January 1971 and February 2000 from each of the 32 plots on 21 occasions at the prescribed age of 4 to 7 months and between the months of November to March. Analyses have included all the major nutrients (N, P, K, Ca, Mg and S) using a wet chemical digestion based on selenised concentrated sulphuric acid (Bishop, 1965). Since 1984 leaf sam-

Table 1. Treatment changes on BT1 since its establishment. Dates refer to the times that treatment changes were made and, except in the fourth cycle, coincided with the dates that new cycles were established (R0 = plant crop). The values in the table indicate the number of replications per treatment.

Date	25 Oct 39		21 Oct 48		11 Oct 57		8 Nov 78		26 Nov 91	
Cycle	**1 R0**		**2 R0**		**3 R0**		**4 R1**		**5 R0**	
Treatment	**B**	**T**	**B**	**T**	**B**	**T**	**B**	**T**	**B**	**T**
Fo	4	4		8		8		8		8
F	4	4		8		8		8		8
M Fo	4	4								
M F	4	4								
t Fo			8		8		4		4	
t F			8		8		4		4	
to Fo							4		4	
to F							4		4	

Abbreviations: Burnt (B) Fertiliser applied (F) No fertiliser applied (Fo) Maize intercropping (M)
Trashed (T) Tops spread (t) Tops raked off (to) Ratoon number (R)

ples were also analysed for micronutrients (Zn, Cu, Fe and Mn) using the procedure described by Wood *et al*. (1985).

Data capture and retrieval

Prior to 2000 data retrieval was difficult to carry out as yield, soil and leaf analysis record storage was mainly in hardcopy files, although a limited amount of data were captured on the old IBM mainframe at SASEX, which was difficult to access. In 2000 all available records pertaining to the history of the trial, yield production, rainfall, temperature, soil and leaf analytical data have been entered into a Windows based data capture and retrieval system (Agrobase).

Results

Yields

The first in-depth investigation into the benefits of trashing in the South African sugar industry was largely based on outcomes from this trial as reported by Thompson (1966). The beneficial effect that trashing had on yields compared with burnt cane management is shown in Figures 1 and 2. Although statistically no significant yield trends were apparent there was a consistent benefit for the trashed over the burnt treatments (for both the fertilised and non-fertilised treatments). This is probably due to factors such as higher rainfall efficiency (Thompson, 1965; Torres and Villegas, 1995), reduced weed competition and superior soil chemical, physical (van Antwerpen and Meyer, 1998) and biological properties (Graham *et al*., 1999). The non-fertilised treatments produced yields similar to those of the fertilised treatments for the first two cycles, which covered a period of 18 years (Table 2) and reflect the high buffering capacity of the Arcadia form soil on which the BT1 trial was established. Another interesting feature was the yield trend between treatments, first where fertiliser was used and secondly where organic matter (trash) was retained on site after harvest (see Figure 1). Although statistically not significant the trashed and fertilised (TF) treatment consistently produced the highest yields in all crop cycles (Figure 1). The yield difference between the two extreme commercial treatments (burnt with no organic matter retained (BtoF) versus green cane harvesting and all organic matter retained (FT)) was 6 tc/ha/an in the fourth crop cycle and 9 tc/ha/an in the fifth cycle. A similar trend in yield difference was noted between the non-fertilised version of these two treatments (BtoFo versus TFo). Also apparent in the non-fertilised treatments, was the higher rate of yield decline in the burnt compared with the trashed treatment (Figure 1).

Table 2. The cycle history of BT1.

Cycle	Variety	Plant date	Crops per cycle	Years per cycle
1	Co281	25-Oct-39	4	9
2	Co301	21-Oct-48	4	9
3	NCo376	11-Oct-57	12	20
4	NCo376	08-Sep-77	11	14
5*	N16	26-Nov-91	9	10

* As in September 2001

In relation to cutting age

Yield trends over the years have shown a decline with time in terms of tons cane per hectare (Figure 2). However, age of the crop at harvest has decreased over time due to the stalk borer *Eldana saccharina* Walker. Expressing yields as tons cane per hectare per annum (tc/ha/an) has shown that yields from the fertilised treatments have actually increased with decreasing cutting age while those from the non-fertilised treatments have

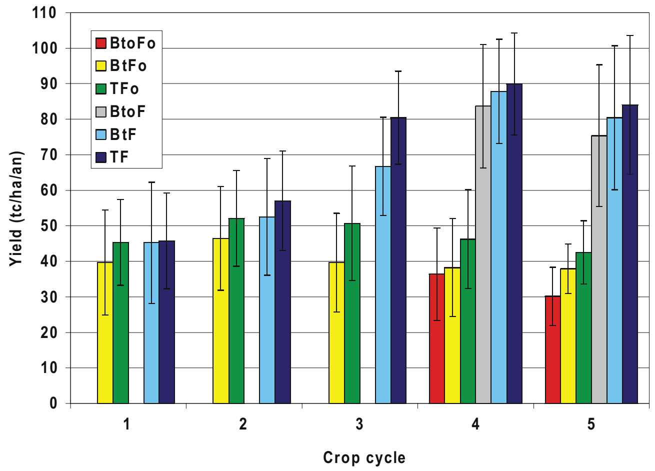

Figure 1. Mean yield per cycle for all treatments from the BT1 trial. The bars represent standard error of the mean.

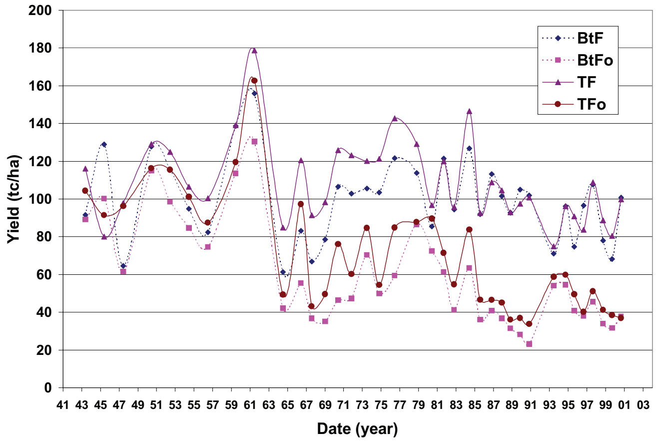

Figure 2. Comparison of cane yield (tc/ha) between treatments from BT1.

remained virtually unchanged below a cutting age of 20 months (Figure 3).

The effect that trashing had on yield can be seen in Figures 2 and 3 where the trashed treatments nearly always produced higher yields compared with the burnt cane. However, the beneficial effect that trashing had on yields from the fertilised treatments decreased after 1980 (Figure 2), not due it is thought to the decreased cutting age (Figure 4) but for nutritional reasons (see section on nutrition). The overall mean residual yield benefit due to trashing was 9.3 tc/ha/an after 39 crops.

In relation to rainfall

Cane yield from the trashed/burnt fertilised treatments was generally related to increasing rainfall when expressed as a percentage of long term mean rainfall. However, in the absence of fertiliser these treatment yields generally showed no correlation with rainfall (see Figure 4). Although the response to trashing was not significant, a comparison of the fitted trend lines for trash and burnt treatment yields indicated a steady decline in the response to trashing with increasing rainfall. The effect was more apparent when fertiliser was present, declining from 10 to less than 3 tc/ha/an (Figure 4).

Although the effect that rainfall had on yield response to a trash blanket might seem small, an overall assessment of the yield response data indicated that positive responses to trashing were possible in wet seasons even where the rainfall was as high as 150% of the long term mean (Figure 4). However, as determined by Thompson and Wood (1967) the response to trashing is more a function of rainfall distribution rather than the amount of rainfall. Only three significant negative responses to trashing were obtained in 39 crops and these were associated with seasons with above average rainfall as well as poor rainfall distribution.

The water preserving property of the trashed layer (Torres and Villegas, 1995) from the fertilised treatment kept the topsoil layers wet for a prolonged period due to continual rain, which could have been a major factor in the net yield loss. The relatively low trash producing capacity of the non-fertilised treatment (15 ton/ha trash compared to 20 ton/ha for the non-fertilised and fertilised treatments respectively) did not lead to a yield loss of the same magnitude as that from the fertilised treatment under the continually wet conditions (Figure 5).

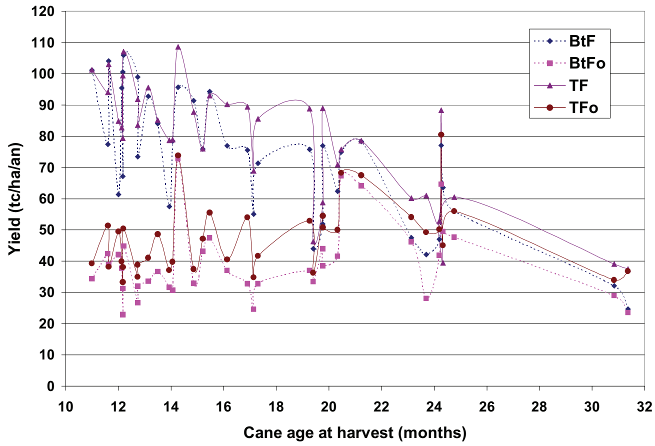

Figure 3. Effect of cutting age on yield (tc/ha/an) between various treatments from BT1.

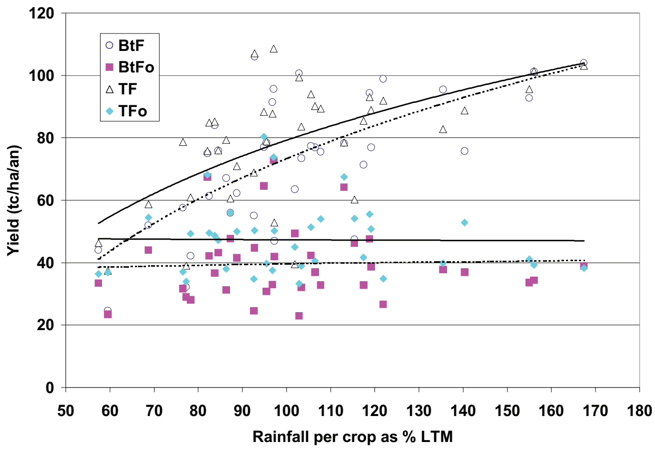

Figure 4. The relationship between yield and rainfall per crop as a percentage of the long term mean (LTM). The solid trend lines represent the trashed treatments and the broken trend lines the burnt treatments. Trend lines were fitted with the Excel trend line function.

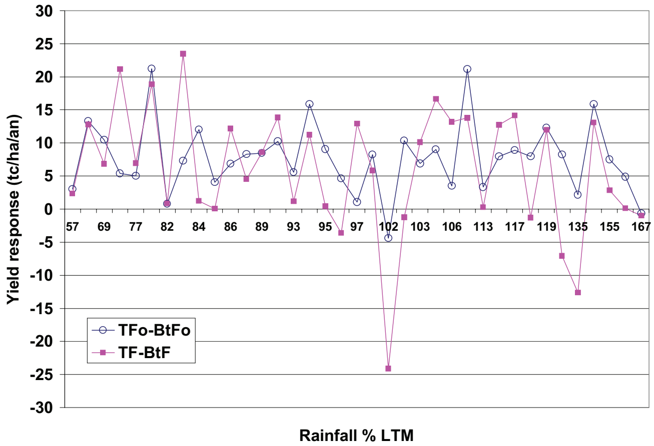

Figure 5. Yield response comparison between the trashed and burnt treatments as affected by rainfall expressed as a percentage of long term mean (LTM).

Trash

The amount of organic matter retained after harvest for the fertilised trashed (TF) treatment was about 20 tons/ha compared with the 15 tons/ha of the non-fertilised trashed treatment (TFo). The fertilised burnt treatment with tops retained and spread after harvest (BtF) produced on average 3.2 tons trash/ha compared with the 2.3 tons/ha from the non-fertilised burnt treatment with tops spread (BtFo). No organic matter was measured from the burnt treatment with all tops removed because only the ash remained and most of it was blown away by the wind within days of harvest.

Cane nutritional trends

The effect of trashing and burning with fertiliser on the main soil chemical properties for selected years is summarised in Table 4. The leaf N, P and K status of sugarcane during the fourth and fifth crop cycles is shown in Figures 6, 7 and 8 respectively. The 'noise' in the graphs after 1983 and 1994 is due to the second driest and worst droughts that were experienced during 1982/3 and 1991/93 respectively in the South African sugar industry. A strong feature for both data sets was the relatively large difference in the nutrient content of soil and leaf samples taken from the fertilised and non-fertilised sections of the trial. However, since the aim of this paper is to emphasise the potential of trashed versus burnt cane, the data will mainly be discussed with respect to the latter.

Soil acidity

Acidification was evident under trash for both the fertilised and non-fertilised treatments as shown by consistently (but not statistical significant) lower soil pH values when compared with those under the burnt treatment (Figure 9). The greater acidification under trash compared with burning is considered to be due to nitrification of ammonium released during mineralisation of the decomposing trash blanket (Wood, 1966). The pH differences between the fertilised and non-fertilised sections within each treatment (i.e. BtFo vs BtF and TFo vs TF) were significant, with the lowest pH occurring in the fertilised section (Figure 9). Over the 30 years of cropping, soil Ca and Mg levels have also declined due to the combined effect of acidification, crop removal and the use of high-grade fertilisers containing relatively small amounts Ca in the carrier compared with those of 40 years ago.

Organic matter

The trash treatment of both the fertilised and non-fertilised sections had a consistently higher soil organic matter content when compared with the burnt treatment. However, the differences in organic matter between the fertilised and non-fertilised sections were less marked. Similar results were obtained from samples taken independently from BT1 by other workers (van Antwerpen and Meyer, 1998; Graham *et al*., 1999). The magnitude of the differences increased for layers closer to the soil surface. These studies all confirmed the importance of trash retention in maintaining and improving soil organic matter status whereas the practice of burning, particularly where tops were removed, has caused a marked loss of soil organic matter over the 59 year period. An important outcome of organic matter accumulation is that the size of the microbial biomass and its respiratory rate, dehydrogenase activity and arginine ammonification rate were also all increased by trash retention (Graham *et al*., 1999). Soil microbial activity was, however, inhibited by fertiliser applications. Subsequent analysis by the Pathology Department at SASEX has revealed that the trashed treatment was beneficial to the accumulation of Burkholdaria[1] numbers relative to the burnt treatment. It was also shown that Burkholdaria numbers were higher for the fertilised section compared with the non-fertilised section.

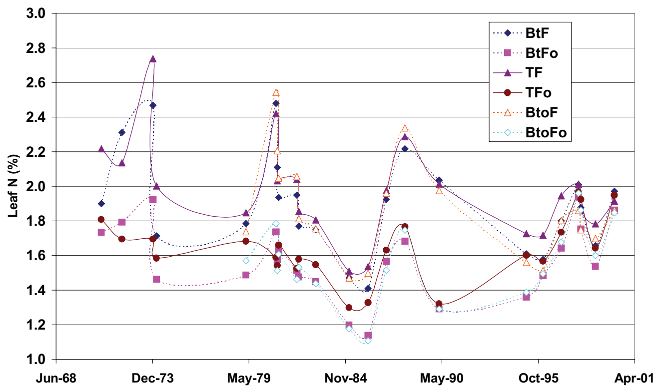

Figure 6. Leaf nitrogen content for various treatments over time.

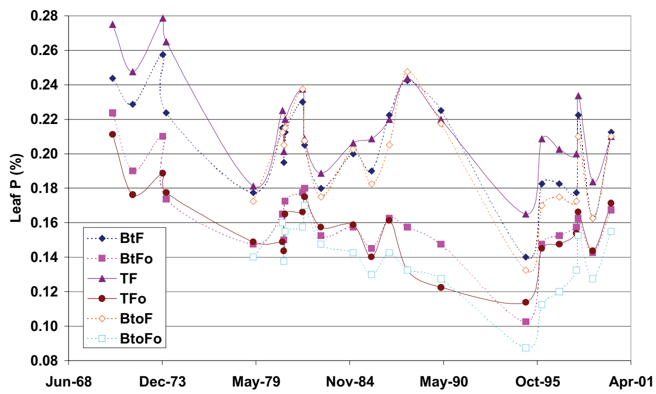

Figure 7. Leaf phosphorus content for various treatments over time.

Nitrogen

In general the third leaf N content of the trashed plots nearly always exceeded that of the burnt plots for both the fertilised and non-fertilised treatments, but the differences never reached significant levels. Not surprisingly the N content of the non-fertilised treatments steadily declined from initially being just above the leaf threshold level of 1.8% in 1971 to 1.4% in 1990. The flush of N mineralised in the soil following the 1991 to 1993 drought increased the overall N status, especially in the non-fertilised treatments, to above the threshold value, thereby nullifying the N difference between the fertilised and non-fertilised treatments (Figure 6). Leaf N levels of fertilised trashed and burnt treatments have generally been well above the threshold value. However, leaf N maxima steadily declined from an average of 2.7% in 1973, to 2.4% in 1979, 2.2% in 1987 and 2.0% in 1997. This draw down in N reflects a decline in the organic N content of soils under continuous cropping.

The improved N uptake under a trash blanket was mainly due to the accumulation of organic matter and total N in the soil surface. Results of a recent investigation have shown that readily mineralisable N was higher under trash retention than burning to a depth of 300 mm and this effect was much enhanced under fertilisation (Graham *et al*., 1999). Soil N inputs from the decomposition of trash are accumulated in time into a readily mineralisable pool of soil organic N (Wood, 1966). The leaf N data presented are further evidence that soil N availability under green cane harvesting was considerably greater than that under burning.

Phosphorus

P uptake under trash retention for both the fertilised and non-fertilised treatments was superior to that of the burnt treatments over the five cropping cycles but, as with N, the differences were not statistically significant (Figure 7). Of interest is that the burnt treatment with all tops removed (Bto) almost consistently had a lower leaf P content than the burnt treatment with all tops spread (Bt). The P content of the non-fertilised treatments steadily declined from a level of P sufficiency (above 0.19%) to a state of deficiency after December 1973. As with N, there was a marked increase in P uptake following the 1991/93 drought but the P mineralised by the soil was not sufficient to correct the P deficiency in the non-fertilised treatments.

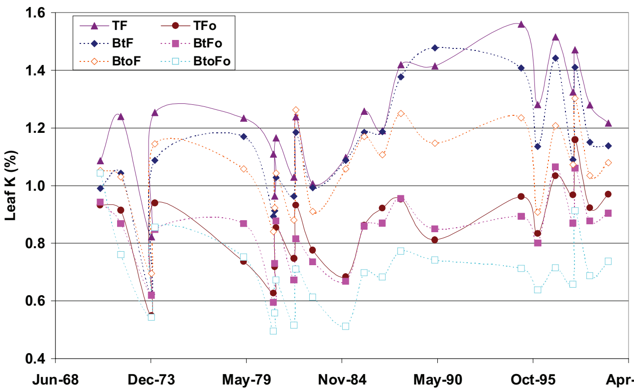

Figure 8. Leaf potassium content for various treatments over time.

Leaf P levels of fertilised trashed and burnt treatments were generally well above the threshold value of 0.19% but leaf P maxima steadily declined from an average of 0.28% in 1973 to 0.21% in 1997. This draw down in P also reflects a run down in the organic P content of soils under continuous cropping.

It is possible that P recycling from the tops and trash was a factor in improving leaf P in the trash treatment. Although the Truog P levels in soil samples taken to a depth of 200 mm did not reflect any build-up of P under a trash blanket, shallower soil sampling to a depth of 50 mm showed a significant accumulation of P under trash retention due to P released during trash decomposition (Graham *et al*., 1999).

Potassium

Both the fertilised and non-fertilised sections benefitted from the trash/tops retention treatments (Figure 8). Possibly K recycling from the tops and trash contributed to the improved leaf K, which was also reflected by soil K trends. Differences between the fertilised and non-fertilised section were negligible. However, though not significant, differences were evident between the trashed and burnt treatments. For the fertilised section these differences were initially in favour of the burnt treatment but after the 1982/3 drought the trashed treatment was and still is higher in plant available soil K, probably due to recycling of K from the trash. The lower exchangeable K levels in the burnt compared with trashed plots suggest a loss of K during burning. This loss was probably as a result of ash being blown off burnt plots by strong winds.

Discussion

The BT1 trial has shown that green cane harvesting has a positive effect on cane yield of about 9 tc/ha/an when compared with the conventional practice of burning before harvest. There could be many reasons for this response but the most likely is an improvement in soil organic matter status. This can, in most instances, be used to explain the behaviour of most other parameters measured.

Nutritional benefits

The more obvious advantage of applied trash when analysed is its nutritional value (Table 2). Although nutritional differences exist between varieties these do not detract from the trend between nutrients. The nutrient value of trash based on an application rate of 20 tons/ha and the nutrient composition values for variety N16 shown in Table 3, together with current unit costs of 2.95, 9.00 and 3.09 R/kg respectively for N, P and K, is R1390/ha.

However, not all the nutrients from the trash layer are immediately available to the plant. Most of them are utilised by soil microorganisms and it is only when they die that a proportion is mineralised and taken up by the plant, and the rest by other microorganisms. It takes several years for a trash system to come to equilibrium with the applied organic matter before substantial fertiliser savings can be made and optimum nutritional levels in the plant maintained. Regular soil and leaf analysis should ensure that the fertiliser benefits are utilised while maintaining optimal nutrient levels in the plant.

Table 3. The nutritional composition of various South African sugarcane varieties.

Variety	kg / 20 t trash / ha								
	N	P	K	S	Ca	Mg	Zn	Mn	B
N12*	104	14	120	14	24	24			
N16*	146	18	258	28	26	26			
N14**	60	12	410	32	36	44	0.44	0.68	0.09
N19**	118	18	272	26	38	50	0.24	0.58	0.11
Average	107	16	265	25	31	36	0.34	0.63	0.10

* Erik Bentley (personal communication)

** AG de Beer *et al*., (1995)

The results of a recent long-term N balance simulation investigation with the APSIM-Sugarcane cropping systems model involving BT1 have underlined the important role the run down in organic matter has played in supplying N to crops. During the life of the BT1 trial, approximately 2 200 kg/ha of N would have been mineralised during the soil organic matter run down, compared with average N inputs from fertiliser of approximately 3 900 kg/ha (Thorburn *et al*., 2001). As the rate of soil organic matter run down decreases, this net input of mineralised N to the system will no longer occur and N limitations to crop growth may increase. This draw down was certainly evident from the declining trend in leaf N which initially showed a benefit from the trashed treatment, but gradually disappeared. However, at this stage it is not recommended that applied N fertiliser be increased, as the rate of soil acidification was found to be highest in the fertilised section of the trial, which was aggravated by the trashed treatment (Figure 9). The potential N from the applied trash is 146 kg/ha, which is equivalent to fertiliser N applied at 140 kg/ha. If the crop utilises a third of the N from the trash then the trashed treatment has access to an additional 50 kg N/ha, which could be one of the reasons for the higher cane yields from this treatment.

The trashed treatment generally had consistently higher leaf P content compared with the burnt treatment although this difference was not supported by the soil P content over time. However, according to the results in Table 3, the potential benefit from the trashed treatment was an additional 18 kg P/ha,

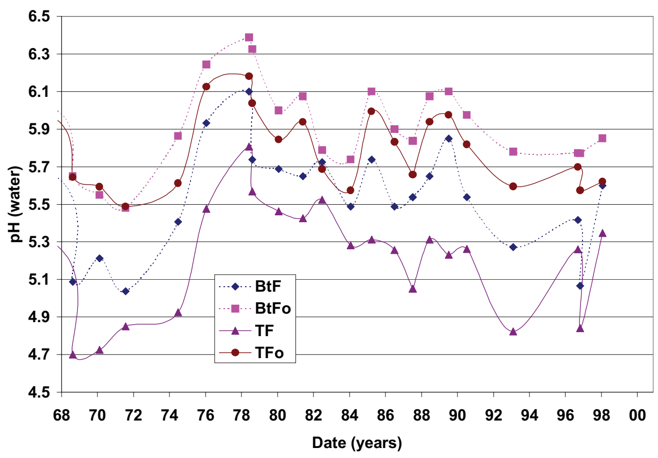

Figure 9. Soil pH trends over a period of 30 years.

which was reflected in the leaf analysis. The fact that it was not reflected in the soil analysis suggests that each time trash is applied, P is taken up as soon as it becomes available. The implication is that the 20 kg P per hectare currently applied leads to marginal levels in the leaf and that the application rate should be increased to 40 kg/ha to maintain P above threshold values in both the leaf and soil.

Potassium is the most abundant nutrient in cane trash (Table 3) and this is probably why increased levels of K were reflected in both leaf and soil samples from the trashed treatment. This treatment benefits from an additional 90 kg K/ha per crop (if a third of the K in the applied trash is utilised by the crop), which may also contribute to the higher yields recorded for this treatment.

Soil microbial biomass and basal respiration have been shown to increase with an increase in soil organic matter, while the metabolic quotient decreases (Graham *et al*., 1999). Thus increased organic matter has led to an increase in microbial C and activity. The higher microbial numbers in turn could lead to an increased rate of organic matter mineralisation, nutrient turnover and production of carbohydrates, leading to more stable aggregates and improved soil physical conditions. These parameters all have an important contribution to the increased crop yields associated with the green cane trash blanket treatment.

Conclusions

The duration of this trial has made it possible to demonstrate the effects of trash blanketing on soil quality and crop yield despite the high buffer capacity of the soil. It was only 18 years after the trial was established that a clear difference in the yield between fertilised and non-fertilised treatments became evident. However, the beneficial effect of the trash was apparent from the start of the trial. The buffering capacity of most other soils is generally lower and therefore the differences between fertilised and non-fertilised treatments would possibly have been apparent much sooner. Notwithstanding that, soil degradation is real and even soils with a marked resistance to degradation eventually start to show the effects that sugarcane monoculture has on the mining of nutrients and downgrading of other soil properties.

Table 4. The effect of trashing (T) and burning (Bt) with fertiliser (F) on the main soil chemical properties for selected dates.

Date	Organic matter (%)		pH (water)		P (mg/kg)		K (mg/kg)		Ca (mg/kg)		Mg (mg/kg)	
	BtF	TF	BtF	TF	BtF	TF	BtF	TF	BtF	TF	BtF	TF
16-Jun-45	5.88	5.81	6.46	6.21	26.00	22.63						
15-Jul-62	7.67	7.87			20.81	12.94	446	396	1521		223	
21-Jul-70			5.21	4.73	25.88	25.25	138	143	2125	1800		
28-Jun-76	4.97	5.24	5.93	5.48	16.50	9.88	114	110	1920	1698		250
02-Jul-80			5.69	5.46	12.25	15.00	137	159		1538		220
02-Jul-84	5.05	5.59	5.49	5.28	11.50	8.75	151	121		1705		
10-Dec-87	5.63	6.09	5.54	5.05	9.18	11.15	152	172		1641		450
12-Dec-90	5.53	5.58	5.54	5.26	15.75	7.50	203	199		1565		350
09-Jul-93			5.27	4.82	16.75	13.13	252	257		1505		
25-Jun-98	4.43	4.65	5.60	5.35	2.67	2.75	115	127	2150	1424	594	

One of the most important ingredients of soils is their organic matter content and every effort should be made to maintain this. A decrease in organic matter content leads to a decrease in the quality of the soil in terms of its chemical, physical and biological properties. Physical properties in particular take time to regenerate and here the saying "prevention is better then cure" is definitely applicable.

This trial is important in the studying of microbial sink/source relationships in sugarcane and the effect that parameters such as organic matter and pH have on these relationships. There are still questions that remain unanswered from this trial:

- Have soil organic matter levels reached equilibrium and, if not how far are they from this point?
- What is the composition and functional diversity of the soil microbial community as affected by the treatments and parameters such as soil acidity?

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[1] Burkholdaria is a bacterium of which 20 species are known. Some of their favorable properties are to improve N use efficiency and reduce Al toxicity. They produce antibiotics, which are anti-fungal and funguses prefer an acid environment. Higher Burkholdaria numbers should therefore be aimed for.