SEASON EFFECTS ON PRODUCTIVITY OF SOME COMMERCIAL SOUTH AFRICAN SUGARCANE CULTIVARS, II: TRASH PRODUCTION

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Abstract

The demand for sugarcane trash as a means of reducing fertiliser inputs by recycling nutrients and improving soil health could be challenged in future by the demand for lignocelluloses as a feedstock for ethanol production. Large quantities of trash may also have deleterious effects on crop growth, and ameliorative steps may be needed to avoid this. A study was therefore undertaken to quantify trash production by various commercial sugarcane varieties, in different seasons. Amounts of trash were measured in three well irrigated experiments which had a range of commercial cultivars and crop start dates as treatments. Potential trash yields ranged from 5.2 to 23.9 t/ha; lowest amounts were produced by CP66/1043 and N21, and highest amounts by N14 and NCo376. Annual trash production potential was affected by crop start/harvest date, with the lowest amounts of trash being produced in winter crops. Large quantities of nutrients (e.g. 146 kg N/ha, 15 kg P/ha and 287 kg K/ha) are contained in trash and could be recycled, but may not be available to the following crop in the short term.

Keywords: sugarcane, trash, yield, varieties, cultivars

Introduction

Sugarcane yields are traditionally reported in terms of cane and sucrose mass, whereas amounts of trash are seldom reported. Furthermore, studies rarely include different cultivar types or consider the effect that season (i.e. the start and harvest dates) may have on all the components of biomass. Advances in technology addressing ethanol production from lignocelluloses will enhance the value of trash. Alternatively, trash left in the field will decompose and release nutrients to the soil. These nutrients need to be considered in determining the appropriate fertiliser programme for maximising productivity. This study reports on three experiments in which annual trash yields were measured. Two experiments included a range of commercial cultivars grown from two and five starting times, and the third experiment was done on N14 grown from three starting dates. The objective of this study is to report on the amounts of trash that were produced by a range of commercially grown cultivars in South Africa under stress-free conditions. The effects that the months at which crops are started and harvested have on the quantity of trash produced are also assessed. A companion paper in these proceedings deals with biomass and radiation use efficiencies (Donaldson *et al.,* 2008). Total potential trash is defined as the total foliage that can be removed from stalks during harvesting; this includes entire shoots that have died during the development of the crop. In practice, some leaf material clings to the stalk and therefore not all potential trash remains in the field. Green foliage is composed of all green leaves, including partially necrotic leaves with more than 50% green area and their associated sheaths. 'Dead trash' includes all leaves and shoots that have died during the development of the crop.

Materials and Methods

Growth and development of well irrigated sugarcane crops were measured in two experiments at Pongola (Experiments 1 and 3, 27°25'S, 31°36'E, 308 m elevation) and one experiment at Mount Edgecombe (Experiment 2, 29º42'S, 31º02'E, 105 m elevation). The experiments were well supplied with nutrients and kept free of weeds at all times. Weather stations, close to each experiment, provided daily data to develop relationships between growth and radiation.

Experiment 1 - Pongola
Ratoon crops of nine cultivars in two replications were started in March, April, May, August and December at Pongola. The experiment consisted of nine cultivars, of which only NCo376, N25 and N26 were common to each of the five start dates. N19 and N22 were in the March and December cycles, CP66/1043 and N24 were in the April and August cycles and N17 and Q124 were in the May cycle only (for further details see Singels *et al*., 2005a). This study focuses on cultivars NCo376, N25 and N26 only (Table 1).

Experiment 2 - Mount Edgecombe
Nine cultivars were planted in two replications during December 1999 at Mount Edgecombe. Half the number of plots was then harvested in June 2000 and the other half in December 2000 to create a winter and a summer cycle (for further details see Singels *et al.*, 2005b).

Experiment 3 - Pongola
Data were extracted from Mount Edgecombe Research Report (MERR) No. 7 (Thompson, 1991), which documents the growth of N14 at Pongola. Data from ratoon crops started in April 1988, August 1988 and October 1988 have been collated as Experiment 3 (for further details see Thompson, 1991).

Table 1. Details of experiments conducted on sugarcane cultivars grown at Pongola and Mount Edgecombe.

Site and plot size	Crop start date	Final age (days)	Cultivar	Reference
Experiment 1 Pongola Plot size: 18-23 m x 11 rows 1.4 m row spacing	03/03/1998	364	NCo376, N25, N26	Singels *et al*. (2005a)
	08/04/1998	365		
	06/05/1998	362		
	06/08/1998	362		
	08/12/1998	357		
Experiment 2 Mount Edgecombe Plot size: 9.5 m x 10 rows 1.2 row spacing	06/06/2000	364	CP66/1043, N12, N14, N16, N17, N21, N27, N29, NCo376	Singels *et al*. (2005b)
	07/12/2000	348		
Experiment 3 Pongola Plot size: 70 m x 11 rows 1.52 m row spacing	19/04/1988	358	N14	Thompson (1991)
	16/08/1988	373		
	12/10/1988	365		

Total plant biomass was measured on several occasions. Dead plant material on and around stalks was collected as trash. The trash thus comprised dead and dying shoots, together with dead leaves. Green foliage was separated from stalks and measured separately as a green component of trash.

The immature top part of the stalk was treated as follows:

- In Experiments 1 and 2 the top immature part of the stalk was analysed separately and the calculated mass was then added to that determined for the remainder of the stalk.
- In Experiment 1, sections of stalk, 20 cm in length, were sampled from the top of the stalk. These provided data from which the mass of the top immature section of the stalk could be estimated. Samples of tops from the two replications were combined before analysis. Each component was weighed immediately after collection. Sub-samples from each component were weighed and then dried to a constant mass, and weighed again to determine dry mass. Dry matter content of each component was calculated from fresh and dry mass, and aerial biomass (dry mass) was the sum of dead trash, green foliage and stalk mass.
- In Experiment 3, whole stalks including the top sections were weighed and analysed together.

A detailed procedure of stalk analysis has been described by Thompson (1991). In Experiment 3, green leaves, trash and stalks were sub-sampled and analysed for a range of nutrients including nitrogen, phosphorus and potassium content (Thompson, 1991).

Light interception measurements
The fraction of photosynthetically active radiation (PAR) was measured on several occasions before canopy closure, in Experiments 1 and 2, with a ceptometer (SF-80 model, Decagon Devices, Pullman, WA, USA). One above-canopy and eight to ten below-canopy readings were done on each plot between 11h00 and 13h00 on cloudless days. Daily fractions were estimated by interpolation and applied to daily incident short wave radiation measured at the weather stations, and the products summed over the season to derive seasonal intercepted short wave radiation (Singels *et al.,* 2005a).

Yield parameters were analysed using residual maximum likelihood (REML) (Genstat, 10th Edition, VSN International Ltd, 2007) to determine standard error of differences for cultivars and harvesting cycles. Yield variables (biomass) were analysed using analysis of variance (ANOVA) and the Chi square test at the 5% significance level.

Results and Discussion

Partitioning of biomass to trash
Biomass is initially composed entirely of foliage because stalks appear only after about eight leaves have emerged (Roberston *et al*., 1998). Thereafter the fraction of foliage decreases (Figure 1) as stalk mass increases (Thompson, 1978; see Figure 2). The larger scatter of data points in Experiment 1 is due to the variation caused by five crop start/harvest dates compared to only two dates in Experiment 2. The data suggest that the partitioning of biomass fractions to foliage was very similar in Experiments 1 and 2, and that the fraction could be relatively stable in annual crops.

Potential annual trash yields
The annual trash yields were generally highest in autumn crops, and decreased through winter into spring at Pongola in Experiments 1 and 3. Trash yields ranged from 5.2 to 23.9 t/ha (Table 2). The trash fractions of biomass suggest that partitioning to foliage decreases through the colder months. After October, partitioning to foliage increased and yields were higher despite low biomass yields in December crops (see Donaldson *et al*., 2008).

At Mount Edgecombe the average potential trash yield in the June crop was 14.74 t/ha (or 0.32 of biomass) compared to 8.4 t/ha (0.26 of biomass) in the December crop. Unlike the crops at Pongola, the partitioning of biomass to trash in the group of cultivars at Mount Edgecombe (Experiment 2) was lower in late summer than in winter crops. The low biomass yields of CP66/1043 (Donaldson *et al*., 2008) and relatively low fraction of potential trash accounted for the low potential trash yields in December, while the low potential trash yields of N21 were due to a low fraction (0.19) of biomass partitioned to foliage. The partitioning of biomass was similar across all the cultivars in the June crop, except for the lower fractions of potential trash in CP66/1043 and N21 in Experiment 2.

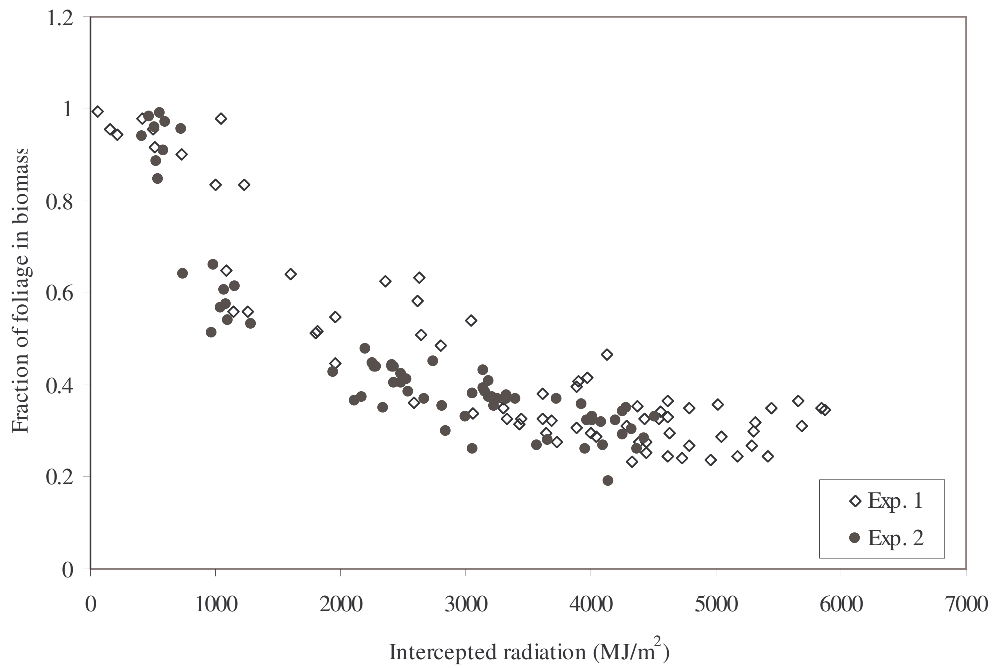

Figure 1. Changes in fractions of sugarcane foliage in biomass in relation to intercepted short wave radiation at Pongola (Experiment 1; open diamonds) and Mount Edgecombe (Experiment 2; closed circles).

Dead and green components of potential trash

There are essentially two layers to a trash mulch blanket. The lower layer consists of decomposing dead shoots that are shaded out during crop development, and dead leaves that are sloughed from older stalks. This is overlaid by a layer composed of dead leaves and green plant material which are parted from the stalks when the crop is harvested. The green trash is composed of green leaves and a short immature stalk top. Plant nutrients are continuously translocated from dying tissue into vigorously growing parts, and therefore the layer of top green trash will contain most of the nutrients that can be recycled into the soil when the trash decomposes. The amounts of dead trash and green trash and their rates of decomposition will determine how nutrients and organic matter are recycled to the soil. Figure 2 shows that potential trash, as a fraction of above-ground biomass, decreases from autumn through winter and then increases into late summer. It appears that the green trash fraction changes in synchrony with potential trash through the season. The dead trash fraction, however, changes little and increases only slightly throughout the season from autumn to late summer. The composition of the trash mulch blanket will therefore change during the season and this may affect the rate at which nutrients are returned to the soil (see van den Berg *et al*., 2006) from annual crops started/harvested at different times of the season.

Table 2. Annual yields of green trash, dead trash, potential trash and fractions of potential trash in biomass.

Cultivar and crop cycle		Green trash (t/ha)	Dead trash (t/ha)	Potential trash (t/ha)	Potential trash as fraction of biomass
Experiment 1					
NCo376	Mar	12.77	9.75	22.52	0.35
	Apr	11.76	12.14	23.90	0.32
	May	6.72	9.52	16.24	0.25
	Aug	5.08	10.19	15.27	0.25
	Dec	8.32	8.82	17.14	0.35
N25	Mar	10.12	7.65	17.77	0.31
	Apr	8.42	9.88	18.30	0.30
	May	9.53	7.90	17.43	0.28
	Aug	5.29	9.03	14.32	0.25
	Dec	6.75	8.99	15.74	0.34
N26	Mar	7.78	5.50	13.28	0.27
	Apr	8.48	10.47	18.95	0.29
	May	9.76	6.69	16.45	0.28
	Aug	4.83	9.04	13.87	0.27
	Dec	9.58	9.26	18.84	0.36
<u>Cultivars</u>	SED	0.53	0.35	0.67	0.01
	LSD(0.05)	1.04	0.69	1.31	0.02
<u>Cultivar*month</u>	SED	1.18	0.78	1.49	0.017
Experiment 2					
June	CP66/1043	7.28	6.66	13.94	0.27
	N12	7.98	7.64	15.62	0.36
	N14	6.21	7.97	14.18	0.32
	N16	6.86	8.92	15.78	0.33
	N17	6.84	5.82	12.66	0.32
	N21	7.58	7.08	14.65	0.28
	N27	5.78	9.70	15.47	0.33
	N29	6.93	8.34	15.27	0.32
	NCo376	7.12	7.92	15.02	0.32
December	CP66/1043	2.32	2.82	5.19	0.26
	N12	6.32	5.73	12.05	0.34
	N14	6.57	6.94	13.51	0.35
	N16	5.61	5.67	11.28	0.30
	N17	4.35	3.55	7.90	0.26
	N21	3.82	3.15	6.99	0.19
	N27	4.19	4.69	8.88	0.28
	N29	4.33	3.79	8.13	0.27
	NCo376	5.07	5.43	10.49	0.29
<u>Cultivars</u>	SED	0.41	0.49	0.81	0.02
	LSD (0.05)	0.80	0.96	1.59	0.03
<u>Month*cultivar</u>	SED	0.57	0.69	1.14	0.02
Experiment 3					
N14	April	11.96	10.45	22.41	0.36
	August	8.15	12.63	20.78	0.27
	October	7.41	8.89	16.30	0.25
<u>Mean</u>		9.17	10.66	19.83	0.28

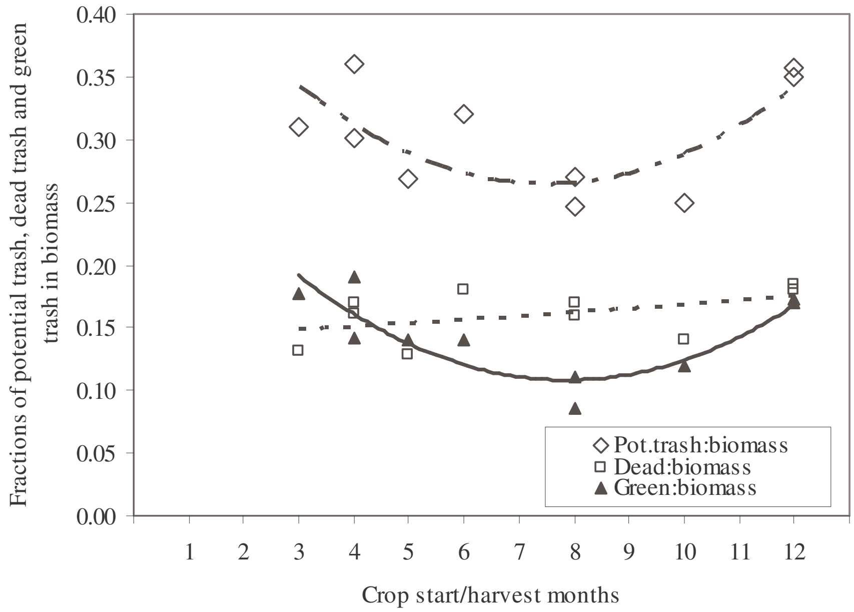

Figure 2. Fractions of potential trash, dead trash and green trash in biomass of annual sugarcane crops grown at Pongola and at Mount Edgecombe. Data points are the mean values of all the cultivars according to season, as listed in Table 1.

Predicting trash yields from cane yields

Cane yields are sometimes used to predict the amount of trash that may be expected from an existing crop (Thompson, 1966). Because the water content in sugarcane stalks is not easily predicted, only biomass (dry mass) is used in many studies. Thus, the relationship between trash dry mass and cane fresh mass may not be reliable because of the variable water content in sugarcane stalks. The relationship may nevertheless be used to develop 'rules of thumb' that can be useful for predicting amounts of trash quickly. For this purpose the relationships between cane yields and potential trash yields of N14 (data from Experiments 2 and 3) and of NCo376, N25 and N26 (data from Experiment 1) are presented in Figure 3.

The relationship between potential trash and cane yields was linear for N14 and curvilinear for NCo376, N25 and N26. The linear model for N14 ($y = 0.0596x + 7.3605$, where x is cane yield t/ha (fresh) and y is trash yield t/ha (dry mass) predicts that a crop of N14 with a cane yield of 70 t/ha will produce 11.5 tons of total trash. Every additional 20 t/ha of cane yield will produce a further 1.22 tons of trash. Thompson (1966) estimated the cane:trash ratio of annually harvested NCo376 grown under dryland conditions at 1.37 m spacing to be 6:1. It was pointed out that row spacing, cultivar, age and cultural practices all affect this ratio (Thompson, 1966). The cane:potential trash ratios were calculated for each cultivar in Experiments 1, 2 and 3. In Table 3, the ratios calculated for N25, NCo376 and N26 in Experiment 1, and for N14 in Experiments 2 and 3, are presented. The mean ratio across cultivars and month of harvest of 9.3:1 is higher than the 6:1 for NCo376 grown under dryland conditions (Thompson, 1966). This could be expected because the crops were well irrigated and grown at wider row spacings. The mean ratio of the December crops was much lower than other months, and this may be associated with the low biomass yields reported by Donaldson *et al*. (2008).

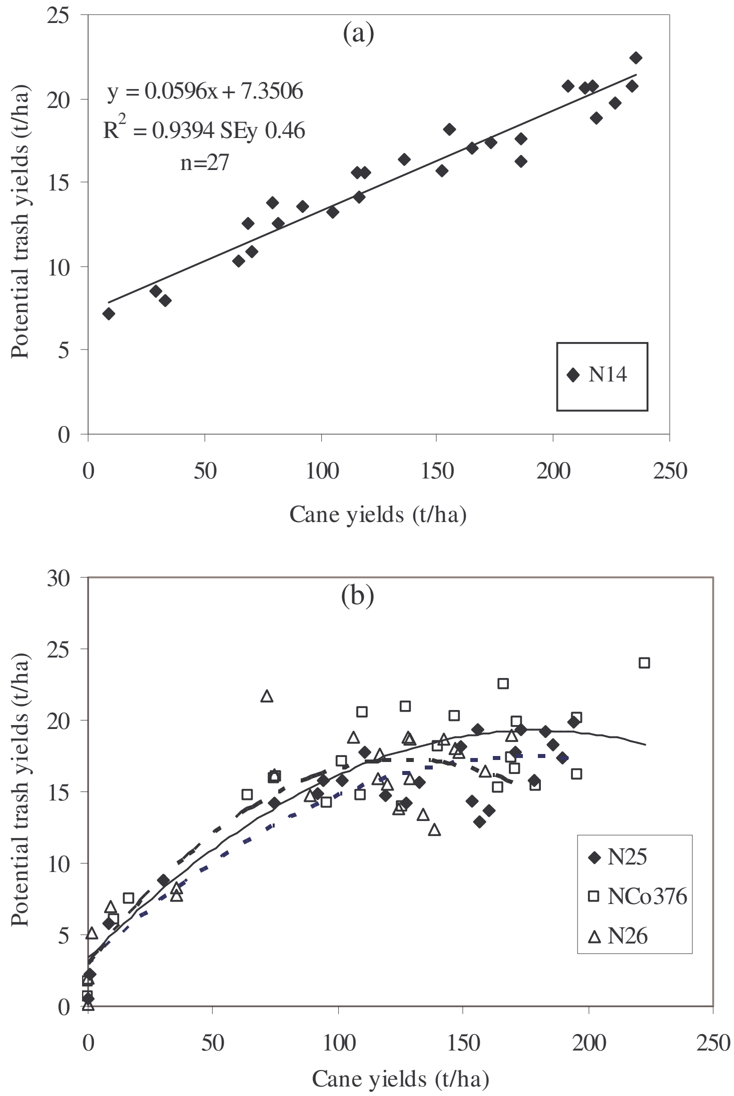

Figure 3. Relationships between cane yields and total trash yields of (a) N14 (data from Experiments 2 and 3) and (b) NCo376, N25 and N26 (data from Experiment 1).

Table 3. Ratios of cane:potential trash yields of sugarcane cultivars harvested annually during different months.

Cultivar	Mar	Apr	May	June	Aug	Oct	Dec	Means
N25	9.6	10.2	10.9		10.7		6.5	9.6
NCo376	7.4	9.3	12.1		10.7		5.9	9.1
N26	10.9	8.9	9.6		8.9		5.6	8.8
N14		10.5		7.4	10.4	11.4	7.7	9.5
Means	9.3	9.7	10.9		10.2		6.4	9.3

Stalk tops in crop residue

At the time of harvesting, the crop residue left in the field as trash is composed of (i) dry material from dead and dying shoots (tillers) and senesced leaves, (ii) green leaves on the stalk and (iii) the top section of stalks that are cut off because they contain little or no recoverable sucrose. Thus far, potential trash has been presented as the combined mass from (i) and (ii). Lengths of tops left as residue after harvesting vary greatly within a crop and between months of harvest. In Experiment 1 the dry mass per cm length of the top 20 cm of the stalk, excluding the very soft apex of the stalk, varied throughout the season and differed between cultivars, as shown in Table 4. From these data the mass of tops of varying lengths can be estimated. For example, the dry mass of tops left as residue in the field from topping at a height of 15 cm below the stalk apex, is estimated to be 11.25, 11.55 and 13.2 g/top for NCo376, N25 and N26, respectively, in annual crops harvested in May. Using stalk populations of 184 545, 133 077 and 140 769 per hectare this would amount to 2.08, 1.54 and 1.86 tons dry tops per hectare for NCo376, N25 and N26, respectively.

Table 4. Dry mass (g/cm) in the top 20 cm of stalks in annual sugarcane crops harvested at different times in Experiment 1 at Pongola.

Month	Mar	Apr	May	Aug	Dec
NCo376	0.49	0.57	0.75	0.46	1.10
N25	0.68	0.48	0.77	1.22	1.46
N26	0.80	0.80	0.88	1.62	1.44

Nutrient content of crop residue

The N, P and K contents in trash, green foliage and whole stalks of annually harvested crops of N14 started in three different months in Experiment 3 at Pongola are presented in Table 5. In Table 6 the amounts of each nutrient in each of the components that form trash have been calculated, assuming that the nutrients are distributed evenly along the length of stalks and that topping produces stalk residue of 2 tons dry mass per hectare.

Table 5. Nitrogen, phosphorus and potassium content (% dry matter) in components of annual crops of sugarcane cultivar N14 in Experiment 3.

Component	Month of harvest	N (% dm)	P (% dm)	K (% dm)
Whole stalk	April	0.32	0.05	0.93
	August	0.25	0.03	0.83
	October	0.23	0.04	1.03
Dead trash	April	0.34	0.03	0.41
	August	0.30	0.02	0.32
	October	0.31	0.03	0.26
Green foliage	April	0.87	0.09	1.89
	August	0.76	0.09	1.68
	October	0.69	0.08	1.68

Table 6. Amounts of nitrogen, phosphorus and potassium (kg/ha) in components of annual crops of sugarcane cultivar N14.

Component	Month of harvest	N (kg/ha)	P (kg/ha)	K (kg/ha)
Tops*	April	6.4	1.0	18.6
	August	5.0	0.6	16.6
	October	4.6	0.8	20.6
Dead trash	April	36	3.1	43
	August	38	2.5	40
	October	28	2.7	23
Green foliage	April	104	10.8	226
	August	62	7.3	137
	October	51	5.9	124
Total aerial biomass (including stalks)	April	267	33.8	640
	August	237	26.4	634
	October	189	27.8	642

*assuming tops have a mass of 2 tons dry mass per hectare

General discussion

Substantial amounts of some nutrients are recycled in trash matter. In these trials, up to 146 kg N/ha, 15 kg P/ha and 287 kg K/ha was returned to the soil via the various trash components of N14 (Table 6), most of which were located in the green trash component. In contrast, Ramakrishnarao and Ramalingaswamy (1982) recorded that during burning of trash, most N was lost, as was up to 75% of P, Ca, Mg, K, Na and Zn, as well as other nutrients. It is tempting, then, to assume that fertiliser amounts can be reduced for cane crops following green cane harvesting. This does not, however, appear to be the case. Ng Kee Kwong *et al.* (1987) showed that crop uptake of N from a trash blanket was negligible and that the N was largely immobilised in the soil organic matter. Other researchers (Thorburn *et al*., 1999; Robertson and Thorburn, 2000, 2007a) have also encountered immobilisation of N during trash decomposition, due to high C:N ratios. This means that most of the N recycled in trash does not become immediately available to the following cane crop; Robertson and Thorburn (2007b) estimate the rate of N release from trash during first 12 months to be slow (1-5 kg N/ha/month), which is of little immediate significance for plant growth. A period of adjustment to the trashed system is required before soil organic carbon and total nitrogen pools come into equilibrium; before this, fertiliser reductions should be made with caution. The period after which equilibrium is reached varies according to environmental conditions, and can range from between 5-10 years (van Antwerpen *et al*., 2002) to between 20-30 years (Robertson and Thorburn, 2007a). To maximise cane production benefits from trashing, Thorburn *et al*. (2002) recommend initially applying up to 60 kg more N/ha under trashed conditions – to feed a bigger crop – but caution needs to be exercised in terms of the economic and environmental soundness of this practice. Trashing is a controversial issue in South Africa's sugar industry due to the obvious advantages and disadvantages inherent in the practice. The biggest impacts that a trash blanket have on the production of sugarcane are the increased amount of water retained (90 mm/annum; Thompson, 1966) and the reduced amounts of herbicides required to control weeds (Murombo *et al*., 1997). Other advantages include the continuous protection of the soil surface against crusting (caused by impact energy of water droplets) on susceptible soils (Table 5, SASRI Soil Identification and Management Working Group, 1999) and therefore improved water infiltration rates, reduced run-off and erosion, improved organic matter content and thus soil health (van Antwerpen and Meyer, 1998). The minimum amount of trash required to realise these advantages is in the order of 10 tons dry trash/ha, which equates to a cane yield of about 60 tons/ha. Below this amount the advantages of a full trash blanket diminish, as is evident in the difference between spreading only the cane tops after burning at harvest, and retaining the trash following green cane harvesting. However, trash blankets can have a negative impact on cane yield when used in situations such as (i) where the soils are continually wet (valley bottom soils with a water table within 500 mm from the surface for a portion of the growing season), (ii) exceptionally wet seasons before the crop has reached full canopy stage (van Antwerpen *et al.,* 2006), and (iii) areas prone to frosting or where minimum temperatures in winter are less than 2ºC.

Conclusions

- Potential trash yields vary greatly due to cultivars and season effects on growth.
- Annual trash yields of more than 20 t/ha can be produced by some current commercial South African cultivars under irrigation. Under certain conditions trash yields could be excessive and may need ameliorative action to mitigate negative effects.
- Trash contains large amounts of nutrients; benefits from recycling nutrients through trash and improving soil health are, however, only likely to be realised over the long term. Annual soil and leaf sample analyses should be used to determine fertiliser application adjustments.
- A cane:trash yield ratio of 9:1 may be reasonably accurate for estimating trash yields of crops grown under irrigation in the northern regions of the South African industry.

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REFERENCES

Donaldson RA, Redshaw KA, Rhodes R and van Antwerpen R (2008). Season effects on productivity of some commercial South African cultivars. I: Biomass and radiation use efficiencies. *Proc S Afr Sug Technol Ass* 81: (in press).

Murombo M, Takavarasha E and Wiseman J (1997). Green cane harvesting at Mkwasine Estate, Zimbabwe. *Proc S Afr Sug Technol Ass* 71: 30-32.

Ng Kee Kwong KF, Deville J, Cavalot PC and Reviere V (1987). Value of cane trash in nitrogen nutrition of sugarcane. *Plant Soil* 102: 79-83.

Ramakrishnarao S and Ramalingaswamy K (1982). A note on loss of nutrients when cane trash is burnt. *Proc Int Soc Sug Cane Technol* 16: 123-129.

Robertson FA and Thorburn PJ (2000). Trash management – consequences for soil carbon and nitrogen. *Proc Aust Soc Sug Cane Technol* 22: 225-229.

Robertson FA and Thorburn PJ (2007a). Management of sugarcane harvest residues: consequences for soil carbon and nitrogen. *Australian Journal of Soil Research* 45: 13-23.

Robertson FA and Thorburn PJ (2007b). Decomposition of sugarcane harvest residue in different climatic zones. *Aust J Soil Res* 45: 1-11.

Robertson MJ, Bonnett GD, Hughes RM, Muchow RC and Campbell JA (1998). Temperature and leaf area expansion of sugarcane: Integration of controlled-environment, field and model studies. *Aust J Plant Physiol* 25: 819-828.

SASRI Soil Identification and Management Working Group (1999). *Identification and Management of the Soils of the South African Sugar Industry*. Third Edition. Published by the South African Sugar Association Experiment Station, ISBN 1-874903-17-4.

Singels A, Donaldson RA and Smit MA (2005a). Improving biomass production and partitioning in sugarcane: Theory and practice. *Fields Crops Res* 92: 291-303.

Singels A, Smit MA, Redshaw K and Donaldson RA (2005b). The effect of crop start date, crop class and cultivar on sugarcane canopy development and radiation interception. *Field Crops Res* 92: 249-260.

Thompson GD (1966). The production of trash and its effects as a mulch on the soil and on sugarcane nutrition. *Proc S Afr Sug Technol Ass* 40: 333-342.

Thompson GD (1978). The production of biomass by sugarcane. *Proc S Afr Sug Technol Ass* 52: 180-187.

Thompson GD (1991). The growth of sugarcane variety N14 at Pongola. Mount Edgecombe Research Report (MERR) No. 7. Published by the South African Sugarcane Research Institute, Mount Edgecombe, South Africa.

Thorburn PJ, Probert ME, Lisson S, Wood AW and Keating BA (1999). Impacts of trash retention on soil nitrogen and water: An example from the Australian sugarcane industry. *Proc S Afr Sug Technol Ass* 73: 75-79.

Thorburn PJ, van Antwerpen R, Meyer JH and Bezuidenhout CN (2002). The impact of trash management on soil carbon and nitrogen. I: Modelling long-term experimental result in the South African sugar industry. *Proc S Afr Sug Technol Ass* 76: 260-268.

van Antwerpen R and Meyer JH (1998). Soil degradation. II: Effects of trash and inorganic fertilizer on soil strength. *Proc S Afr Sug Technol Ass* 72: 152-158.

van Antwerpen R, Meyer JH and Thompson GD (2006). The impact of trashing on yield response in the South African sugar industry: A summary of results from several BT trials. *Proc S Afr Sug Technol Ass* 80: 130-133.

van Antwerpen R, Thorburn PJ, Horan H, Meyer JH and Bezuidenhout CN (2002). The impact of trash management on soil carbon and nitrogen. II: Implications for sugarcane production in South Africa. *Proc S Afr Sug Technol Ass* 76: 269-280.

van den Berg M, Jones M and van Antwerpen R (2006). Modelling trash management and its impacts: Model performance. *Proc S Afr Sug Technol Ass* 80: 159-162.