

THE PRODUCTION OF TRASH AND ITS EFFECTS AS A MULCH ON THE SOIL AND ON SUGARCANE NUTRITION*

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Introduction

Trash conservation is practised primarily to obtain a reliable means of weed control in ratoon crops of sugarcane, and in Natal it is done with the knowledge that a crop yield response may also be obtained, due largely to moisture conservation in an area where rainfall is severely limiting to crop production. However, in considering the conditions which might be associated with a response to mulching compared with burning, it is essential to recognise that each response might be the sum of several positive effects, and even the net result of both positive and negative effects. The production and composition of trash have therefore been studied, and long-term burning vs. trashing experiments have provided a means for measuring the effects of trash on the soil and crop nutrition.

Trash Production

The progressive accumulation of trash was measured in a growth analysis experiment where variety N:Co.376 was harvested from six replications at weekly intervals. Additional plots, harvested at monthly intervals, were used to study the effects of other treatments which included varieties N:Co.310 and N:Co.382, variety N:Co.376 planted at 1 ft. 6 in. row spacing, variety N:Co.376 irrigated, and variety N:Co.376 without nitrogen fertilisation. The trash consisted of all dead leaves and the immature cane tops above the point of attachment of the sixth sheath on the stalk, and these two components were weighed and sampled separately at each time of harvest.

It is usual to refer to the amount of trash produced per acre in terms of the amount of harvested stalk. This convention has the practical convenience that the weight of trash can readily be estimated from the sugarcane yield, but the value of the information in the field is invariably limited since the moisture content of the trash material is not known. The moisture contents of the representative samples of trash were therefore determined, and the amounts of oven-dry trash produced per acre at various stages of crop development in the different treatments are shown in Table I.

Table I

Oven-dry trash produced under different treatments at various stages of sugarcane crop growth

Treatment	At 12 months of age	At 18 months of age	At 40 tons cane/acre
N:Co.310	6.9	11.7	8.7
N:Co.382	6.9	8.9	6.5
N:Co.376, dryland	6.1	8.8	6.3
N:Co.376, irrigated	9.7	11.4	7.1
N:Co.376, 1 ft. 6 in. spacing	7.1	10.2	7.9
N:Co.376, no nitrogen	3.2	5.8	—

For variety N:Co.376, produced in six replications under standard dryland conditions, the amount of oven-dry trash increased from 3.9 tons per acre at 5 months of age to over 8 tons per acre at 20 months of age. The amount of millable cane increased from 10.6 tons at 5 months to 57.3 tons at 20 months. Approximately a two-fold increase in the amount of trash produced was thus accompanied by a five-fold increase in millable cane.

A rapid increase of the millable cane/oven-dry trash ratio over the period from 5 months to 10 months of age was common to all varieties and treatments, but the absolute values of the ratios appeared to vary significantly, and to maintain different levels during the period of gradual increase after the crop was 10 months old. Varieties N:Co.376 and N:Co.382 were fairly similar, as shown in Figure 1, but for variety

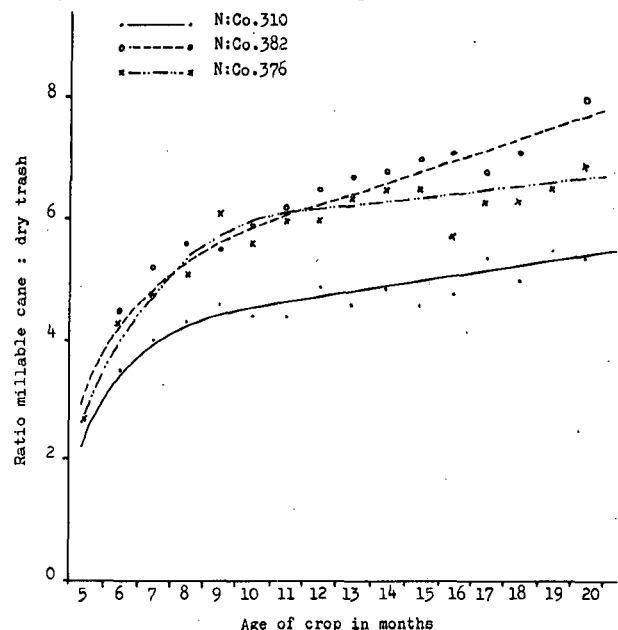


FIGURE 1 : Ratio of millable cane to oven dry trash for three varieties of sugarcane.

N:Co.310 the ratio was low throughout the duration of the crop. The omission of nitrogen fertilisation did not affect the cane/trash ratio, both vegetative components of the crop simply being produced in lesser quantities. Irrigation, however, increased the cane/trash ratio whilst closer spacing of the cane rows caused the ratio to be lower.

It is clear that no single ratio can be used to estimate dry trash from the amount of harvested cane since variety, age and cultural treatment all affect it. However, for variety N:Co.376 under dryland conditions at 4 ft. 6 in. spacing after 12 months of age, a ratio of 6 : 1 may be reasonably accurate.

Nutrient Content of Trash

In comparing the two most common field practices, burning and trash blanketing, for the nutrition of the succeeding ratoon crop, it should be appreciated

*This paper contains mainly material used for post-graduate work in the Department of Crop Science, University of Natal.

that burning probably causes only a loss of nitrogen, the mineral constituents of the trash remaining largely in the ash left on the land after burning. On the other hand there may be some advantage to be gained from the gradual release of nutrients from decomposing trash in contrast to the rapid return to the soil which is effected by burning. If the singed tops remain on the land after burning there may still be a significant conservation of nitrogen which is held in the apical meristem in high concentrations.

Translocation of nutrients from the ageing leaf tissue to the vigorously growing parts of the sugarcane plant is known to occur, so that the dead leaf tissue is not as rich in nutrients as the green leaves. Furthermore, nutrients are leached from the dead leaves and re-enter the soil even before the crop is harvested. The composition of the trash left in the field after harvesting therefore does not represent either the total return of nutrients to the soil from the above-ground parts of the previous crop, nor the entire difference in nutritional effects between burning and trashing. It is of interest primarily as an indication of the approximate amounts of nutrients conserved in this manner, and as a measure of the potential loss of nitrogen when burning is complete. The amounts of nutrients contained in the trash residue from 40 tons of cane per acre in the growth analysis experiment are shown in Table II.

Table II
Nutrients in trash from 40 tons of cane per acre for various treatments

Treatment	N	P	K	Mg Ca	
				lb	lb
N:Co.310	85	4	83	37	45
N:Co.382	71	8	99	28	35
N:Co.376	69	8	76	27	38
N:Co.376, irrigated	81	9	149	34	41
N:Co.376, 1 ft. 6 in. spacing	100	12	136	29	52
N:Co.376, no nitrogen	45	7	70	26	26

Both nitrogen and potassium were returned to the soil in considerable quantities, and thorough burning would have resulted in a loss of nitrogen which could have affected the nutrition of the succeeding crop. The mean yield from six replications of N:Co.376 at 19 months of age was 55.0 tons of cane per acre, and the amounts of nutrients in the total trash per ton of cane were as follows:

N : 1.27 ± 0.125 lb.
P : 0.14 ± 0.012 lb.
K : 1.36 ± 0.164 lb.
Mg : 0.52 ± 0.054 lb.
Ca : 0.76 ± 0.080 lb.

The results from the growth analysis experiment are compared in Table III with data obtained by Golden and Ricaud (1963) in Louisiana in particular, and average results from other parts of the world. The local results were characterised mainly by the low amounts of P in the trash, despite a standard fertilisation of 800 lb. superphosphate per acre in the furrow at the time of planting.

Table III

Nutrient contents of trash per ton of millable cane harvested in various countries

Country/variety	N	P	K
	lb	lb	lb
Louisiana	2.29	0.28	2.52
"World-wide" average	2.00	0.44	2.32
Natal:			
N:Co.310, 40 tons cane/ac	2.13	0.10	2.08
N:Co.382, 40 tons cane/ac	1.77	0.20	2.46
N:Co.376, 40 tons cane/ac	1.73	0.21	1.92

Effects of mulching on the soil and on crop nutrition

These effects were studied mainly in three burning vs. trashing experiments.

Experiment I: Four replications of a split plot experiment were planted in October, 1939 on a Rydalvale clay loam at Mount Edgecombe to compare four treatments:

- (i) plots burnt, mixed NPK fertiliser applied
- (ii) plots burnt, no fertiliser applied
- (iii) plots trashed, mixed NPK fertiliser applied
- (iv) plots trashed, no fertiliser applied.

The experiment was continued uninterruptedly through three successive cycles, each cycle consisting of plant cane and three ratoon crops.

Experiment II: Planted in October, 1947, this experiment was designed to compare three trash treatments in six replications:

- (i) trash blanket
- (ii) trash burnt, tops removed from plots
- (iii) trash burnt, tops spread on plots.

Sub-plot treatments consist of three fertiliser treatments:

- (i) P with one level of N (NP)
- (ii) P and K with one level of N (NPK)
- (iii) P and K with two levels of N (NNPK).

The site was on a Waldene fine sandy loam at Chaka's Kraal and the experiment was conducted through a cycle of a plant crop and two ratoons, followed by a plant crop and five ratoons.

Experiment III: This experiment was designed to study the effects of different amounts of trash on sugarcane yields and did not include any burning treatments. Trashing was therefore made a sub-plot factor in a split plot design with two levels of N (120 lb. and 240 lb. per acre) as the whole plot treatments, and there were six replications. The trash treatments were 0, 7, 16 and 25 tons of trash per acre. The experiment was planted in July, 1955 on a Waldene fine sandy loam at Chaka's Kraal, and was continued through four ratoon crops.

Soil Nutrients

Experiments I, II and III were soil-sampled intensively, plot by plot, during 1962. The samples were taken by 3-inch strata down to 12 inches and were analysed for available P, K, Ca and Mg. The results for the 0-3 inch stratum are shown in Table IV.

Table IV

Available nutrients in the surface 3 inches of soil in Experiments I, II and III

Experiment	Treatment	p.p.m.			
		P	K	Ca	Mg
I	Trash, no fertiliser	3	126	2560	762
	Trash, fertilised	8	178	2250	629
	Burnt, no fertiliser	3	140	2490	772
	Burnt, fertilised	16	196	2520	634
II	Trash blanket	58	71	591	98
	Burnt, tops removed	73	70	547	74
	Burnt, tops left	65	78	648	102
III	No trash	13	83	513	143
	7 tons trash/ac	11	73	557	178
	16 tons trash/ac	11	97	533	179
	25 tons trash/ac	12	119	538	201

Even after 23 years of treatment in Experiment I the soils in burnt plots showed no depletion of major mineral elements compared with the soils from trashed plots. The effects of P and K fertilisation were apparent, and the much heavier crops removed from the fertilised plots presumably caused the significant depletion of Mg in the soils in these plots compared with those in unfertilised plots.

No marked differences in available soil nutrients were apparent in Experiment II after 15 years of treatment, except for an apparent depletion of magnesium where the burnt tops were removed from the plots. In Experiment III the increasing amounts of trash did not cause significant differences in the amounts of available P, K and Ca in the soil, but the amounts of available Mg increased with successive trash increments. The analyses of soil samples from the 3–6 in., 6–9 in., and 9–12 in. strata were similar to those of the 0–3 in. stratum samples, but the variations in available Mg content tended to decrease with increasing soil depth.

Total exchange capacity, total cations and pH

The soil samples from 3-inch strata down to 12 inches in Experiment I were analysed for total exchange capacity, total cations and pH. The results are shown in Table V and although differences were not always significant, it was apparent that trashing increased the total exchange capacity of the soil compared with burning. Trashing also caused an

Table V

Mean data for total exchange capacity, per cent base saturation and pH in successive soil strata in Experiment I

Soil Depth	Total exchange cap., me/100g		Base saturation %		pH	
	Burnt	Trashed	Burnt	Trashed	Burnt	Trashed
0–3 in.	41.9	48.4	50.9	40.6	5.91	5.71
3–6 in.	40.9	41.2	52.8	51.3	6.06	5.36
6–9 in.	43.6	52.8	48.4	39.1	6.12	5.90
9–12 in.	47.2	52.4	43.8	36.4	6.14	6.01

increase in acidity, reflected both in lower pH's and lower per cent base saturation of the soils from trashed plots. The data for similar samples from Experiments II and III showed the same consistent effect of trash in lowering soil pH.

The increase in total exchange capacity of the soil in Experiment I tended to be greater in the presence than in the absence of fertiliser. This effect probably derived mainly from the greater amounts of trash in the fertilised plots, since the results for Experiment III showed that the total exchange capacity of the soil increased progressively with increasing amounts of trash.

Experiments II and III were both sited on Waldene fine sandy loam soils at Chaka's Kraal. A third experiment involving burning and trashing treatments was planted on this same soil series in 1959, and soil samples from the 0–1 in. stratum were taken from all three experiments in 1964. The mean data for the total soil exchange capacity, comparing treatments without trash and treatments with the maximum trash blanket, were as follows:

Experiment II: an increase from 7.05 to 9.14
= 2.09 meq/100g soil after 17 years.

Experiment III: an increase from 6.98 to 8.55.
= 1.57 meq/100g soil after 9 years.

Additional experiment: an increase from 6.53 to 6.95
= 0.42 meq/100g soil after 5 years.

There was thus evidence that the effect of trash increased with time, which was possibly a further expression of the effect of amount of trash.

Available soil moisture

Undisturbed soil cores, 4 in. in diameter and 3 in. deep, were taken from the surface soil of all plots in Experiments II and III in July, 1964. Field capacity was determined at $\frac{1}{3}$ -atmosphere tension in the laboratory on these samples and wilting point was determined at 15 atmospheres tension on disturbed samples taken from the same soil depth. The results are shown in Table VI.

Table VI

The effects of trash treatments on soil moisture characteristics in Experiments II and III

Experiment	Treatment	Amount of water/3 in. of soil		
		Field capacity	Wilt. point	Available
II	Trash blanket	<i>in.</i> 0.64	<i>in.</i> 0.27	<i>in.</i> 0.37
	Burnt, tops left	0.62	0.26	0.36
	Burnt, tops removed	0.58	0.20	0.38
III	No trash	0.64	0.28	0.36
	7 tons trash/ac	0.68	0.32	0.36
	16 tons trash/ac	0.68	0.32	0.36
	25 tons trash/ac	0.67	0.30	0.37

The effects of trash mulching on both field capacity and wilting point were significant in Experiment II, but in these Waldene series soils there was no apparent change in available water held between these limits. Tension curves were not established for any of these soils and it is therefore not possible to comment on the effects of trash treatments on the relative availability of water held between $\frac{1}{3}$ and 15 atmospheres tension.

Undisturbed cores and disturbed samples were also taken from the surface 3 in. of a Rydalvale clay loam soil in plots adjacent to Experiment I in 1963 and 1964. In the absence of any crop, eight plots had been trash-covered and eight plots had been kept bare for 30 months. The mean results of laboratory determinations of field capacity at 3 different tensions and wilting point at 15 atmospheres tension, after 15 months and after 30 months of treatment, are shown in Table VII. The effects of treatment were highly signi-

Table VII

Soil moisture retention in a Rydalvale clay loam after 15 months and 30 months of treatment

Year	Characteristic	Amount of water/3 in. of soil	
		Trashed plots	Bare plots
1963	Field capacity at 50 cm. tension	<i>in.</i> 1.25	<i>in.</i> 1.06
	Field capacity at 100 cm. tension	1.22	1.02
	Field capacity at 330 cm. tension	1.19	0.99
	W. Pt. at 15 atm. tension	0.69	0.59
	Available moisture, $\frac{1}{3}$ to 15 atm.	0.50	0.40
1964	Field capacity at 330 cm. tension	0.98	0.85
	W. Pt. at 15 atm. tension	0.66	0.59
	Available moisture, $\frac{1}{3}$ to 15 atm.	0.32	0.27

ficant on all three moisture characteristics at both times of sampling. The large differences in mean available water content on the two occasions was difficult to explain, and it is of interest that Salter and Williams (1963) found similar effects, due to season, in soils with and without farmyard manure. From December, 1960 to August, 1961, the available water per unit volume of soil had changed from 1.05 to 0.59 in the untreated soil, and from 1.32 to 0.89 in the treated soil. These authors also determined that the additional available water in the manure-treated soil was advantageously held at low tensions.

Soil organic matter

The variations in organic matter content in 3-inch strata of soil down to 12 inches depth in Experiment II are shown in Figure 2. The difference between burning and trashing treatments was significant in the 0-3 in. stratum, but not at other depths. The patterns of variation in Experiments I and III were similar to those in Experiment II, the organic matter contents of the soils decreasing with depth, and the trash-mulched soils containing more organic matter than the unmulched soils.

A summary of the average organic matter contents of soil samples taken from Experiments II and III to a depth of only 1 inch in 1964 is shown in Table VIII.

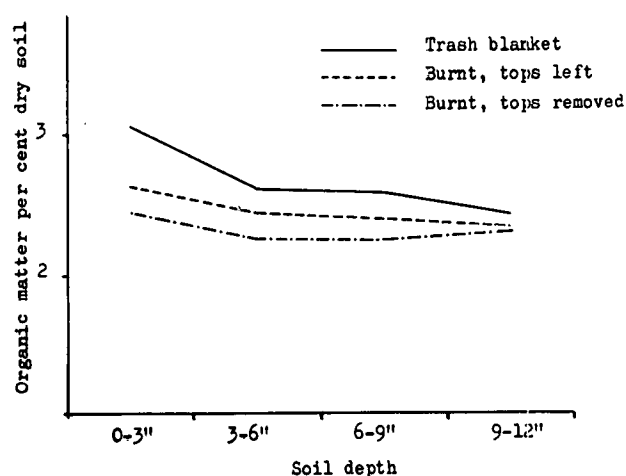


FIGURE 2 : Soil organic matter content by 3 in. strata down to 12 inches in Experiment II

As was to be expected, the effects of trash were much more marked in samples from the shallow surface layer of soil, and it may be noted that the effects in Experiment III were highly significantly linear over the range from 0 to 25 tons of trash per acre.

Table VIII

Average organic matter contents of the 0-1 in. soil stratum in Experiments II and III

Experiment	Treatment	Organic matter
II	Burnt, top removed	% 2.52
	Burnt, tops left	3.33
	Trash blanket	4.07
III	No trash	2.54
	7 tons trash/ac	3.40
	16 tons trash/ac	4.47
	25 tons trash/ac	5.42

Soil Crumb Structure

The water stability of soil crumbs greater than 0.5 mm. in diameter was determined by the method of Beater (1962) in samples from all 3-inch strata down to 12 inches in Experiment I and to 6 inches in Experiment III. The results for Experiment I are shown in Table IX, and it is apparent that, whilst water stability of soil crumbs was always greater for trashed plot soils than for burnt plot soils, the condition was most exaggerated in the 0-3 in. depth. The marked increase from the 0-3 in. stratum to the 3-6 in. stratum under burnt conditions, in contrast to the slight decrease over the same depths under trash, may be construed as evidence that the effect of the mulch treatment was to protect the water stability of crumbs more than to create water stability. The differences at 6-9 in. and 9-12 in. depths may have been due to improved conditions under trash in the current cycle, but the effects of soil inversion at previous plough-outs cannot be ignored.

The results of the analyses for the Waldene soil in Experiment III are shown in Table X. The vast inferiority of the Waldene series compared with the Rydalvale series in terms of water stability of crumb structure was shown in the values for total percentage of water stable aggregates greater than 0.5 mm. in

Table IX
Water stability of soil crumbs by 3 in. strata in Experiment I

Soil Depth (in.)	Treatment	Water stable crumbs (% dry soil)			
		0.5-1 mm	1-2 mm	> 2 mm	Total > 0.5 mm
0-3	Trashed Burnt	21.18	17.78	7.48	46.44
		17.50	10.83	3.29	31.62
3-6	Trashed Burnt	22.34	18.85	6.87	48.06
		21.46	15.44	5.67	42.57
6-9	Trashed Burnt	20.57	20.13	6.52	47.22
		20.62	17.05	5.72	43.39
9-12	Trashed Burnt	19.51	22.78	7.26	49.54
		19.23	20.51	6.51	46.24

diameter in the surface 3 in. of the two soils. The Waldene average was 4.5 per cent and the Rydalvale 39.0 per cent. The results for the soils from Experiment III showed further that the water stability of

aggregates increased consistently with amount of trash, and also tended to confirm the observation that mulching protected water stability of crumbs.

Table X
Water stability of soil crumbs for four trash treatments in Experiment III

Soil Depth (in.)	Treatment	Water stable crumbs (% dry soil)			
		0.5-1 mm	1-2 mm	> 2 mm	Total > 0.5 mm
0-3	No trash	1.26	0.38	0.12	1.77
	7 tons trash	2.70	1.24	0.38	4.32
	16 tons trash	2.93	1.30	0.56	4.80
	25 tons trash	3.87	2.19	0.91	6.98
3-6	No trash	1.82	0.48	0.14	2.44
	7 tons trash	2.38	0.86	0.33	3.57
	16 tons trash	2.57	1.11	0.42	4.10
	25 tons trash	2.81	1.16	0.43	4.40

Soil Bulk Density and Porosity

The effect of trash mulching on the bulk density of the soil was studied on five separate occasions. Two-inch diameter undisturbed cores were taken from the surface soil of the interrow of each plot of Experiment I in 1961. The mean bulk densities for treatments were 1.14 g/cc in the trashed plots and 1.16 g/cc in the burnt plots, the difference not being significant. The corresponding porosities were 53.9 and 53.1 per cent respectively.

Four-inch diameter cores were taken from Experiments II and III during 1964 and the bulk density results are shown in Table XI. There were no significant differences due to treatments and no trends were apparent.

Bulk densities were also determined on the undisturbed core samples taken from the plots adjacent to Experiment I on a Rydalvale clay loam in 1963 and 1964. No significant differences due to trash mulching were apparent, the mean bulk densities for the bare soils being 1.06 and 1.04 g/cc and for the mulched soils 1.09 and 1.07 g/cc in 1963 and 1964 respectively. The average porosities of the bare and

Table XI
Bulk densities in g/cc for the surface 3 in. of soil in Experiments II and III

Experiment	Treatment	Bulk density of soil
II	Burnt, tops removed	1.46
	Burnt, tops left	1.52
	Trash blanket	1.46
III	No trash	1.56
	7 tons of trash per acre	1.58
	16 tons of trash per acre	1.58
	25 tons of trash per acre	1.56

mulched soils in 1963 were 53 per cent and 54 per cent respectively.

Soil Temperature

The effects of a trash mulch on soil temperature in the presence of a crop were studied in a ratoon of N:Co.310 on a Rydalvale clay loam. Of the area selected for this work, half was harvested in July, 1962, and the remainder left unharvested when the

standing crop was approximately a year old. The two halves were then further sub-divided, one quarter being treated with a trash blanket after harvesting, a second quarter being cleared of trash after harvesting, a third quarter being given a fresh trash blanket although unharvested, and the fourth quarter being cleared of all trash although unharvested. Soil temperatures were read daily from thermometers placed midway between the centre of the row and the centre of the interrow at 1 in., 4 in. and 9 in. depths. The results for the 1 in. depth at 8 a.m. in terms of five point moving averages of weekly means are presented in Figure 3.

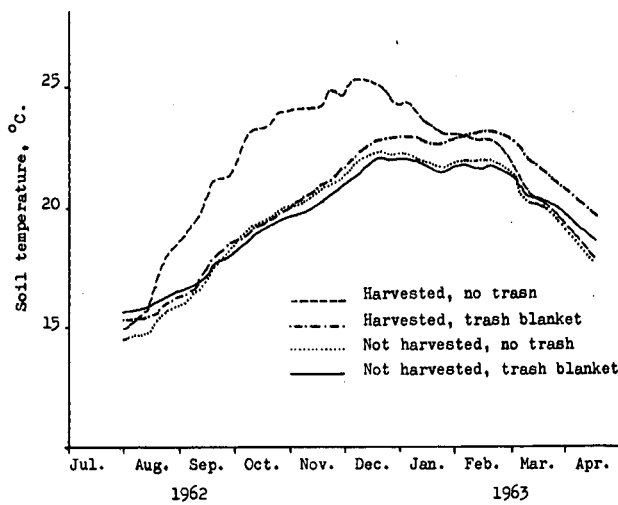


FIGURE 3 : Five point moving averages of mean weekly soil temperatures at the 1 in. depth at 8 a.m. for four treatments

The most marked effect by far was the high soil temperature in the absence of trash where the cane had been harvested. Differences between bare and mulched soil temperatures were maintained at mean values of about 4° C during the spring period when the cane canopy was developing in the harvested plots, but from January onwards when the canopy was well developed, the differences became small. After February, in fact, the mulched soils had a higher temperature at the 1 in. depth at 8 a.m. than the unmulched soils, due indubitably to the combined effects of mulch and canopy in reducing nocturnal longwave back radiation. The same effect was apparent from the data for unharvested plots, although to a much smaller degree. Only for the five-month period from October through March was daily insolation sufficiently great on the unmulched plots for the 8 a.m. temperatures at the 1 in. depth to exceed those of the mulched soils. Thus in winter the effect of the mulch generally was to cause early morning temperatures to be slightly higher than those in plots with bare soil.

The 3 p.m. data for the same plots at the 1 in. depth are shown in Figure 4. Mean differences in temperature between mulched and unmulched soils at this time of day in the harvested plots reached more than 9° C in spring and summer, and the differences were apparent throughout the period of measurement, although a sharp decline developed in February. Distinctly higher soil temperatures in the unharvested

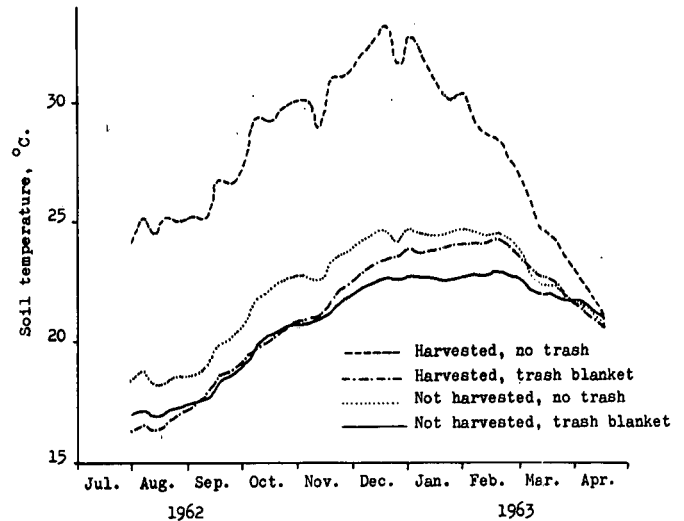


FIGURE 4 : Five point moving averages of mean weekly soil temperatures at the 1 in. depth at 3 p.m. for four treatments

plot without trash compared with those in plots with trash indicated that soil insolation occurred even through a well-developed cane canopy. The presence of the canopy, however, reduced the temperature difference between treatments to about 2° C at 3 p.m.

An additional feature apparent in Figures 3 and 4 was that the trash mulch tended to smooth out the intraseasonal soil temperature variations both at 8 a.m. and at 3 p.m.

The patterns of soil temperature change at the 9 in. depth were similar to those at the 1 in. depth, but the temperatures at the 9 in. depth at 8 a.m. were higher than those at the 1 in. depth except for the 3-month period from September to December, when the temperatures at the 1 in. depth were very slightly higher than those at the 9 in. depth. The 3 p.m. data for the 9 in. depth were much lower than the comparable 1 in. depth data throughout, particularly for the harvested plots without trash. The important feature of these results was that even at 3 p.m. the soil temperatures at the 9 in. depth in the trash mulched plots exceeded those in the unmulched plots from early in March onwards.

The mulch treatments reduced diurnal soil temperature variations markedly. The mean daily range of temperature in the unharvested plots without a trash mulch was reasonably close to 2° C from July through to April, and this was regarded as the effect of a fairly complete leaf canopy alone. In contrast, the mean range varied from 4° C to more than 6° C on the harvested plots without trash during the period of canopy formation, and then dropped to a comparable 2° C by the end of the summer. In the presence of trash, however, the mean daily variation tended to be less than 1° C whether or not a cane leaf canopy existed. Thus the unmulched soils always received more energy than the mulched soils during the day, but the amount of back radiation from these same exposed soils was so great in March and April that the maximum soil temperatures during the day were lower than those in the mulched soils.

The effects of different amounts of trash on soil

temperatures in the absence of a crop were studied on a Waldene series soil where small plots were covered with nil, 1 ton, 2 tons, 4 tons, 8 tons and 16 tons of trash per acre. On 29th September, 1964, the weather was cloudy and cool and the results of temperature measurements at the 5 cm. depth are shown for only three treatments in Figure 5.

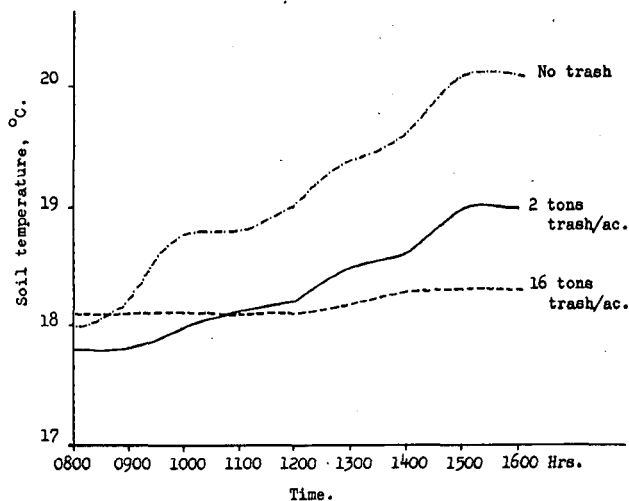


FIGURE 5 : Mean soil temperatures for three treatments at the 5 cm. depth in a Waldene series soil on 29/9/64

The effective protection against nocturnal back radiation by 16 tons of trash per acre was apparent since the temperature of the soil in this treatment was higher than those in plots with no trash and 2 tons of trash per acre at 8 a.m. Within the ensuing hour, however, insolation on the bare soil had reversed the situation, but the reversal did not occur until 11 a.m.

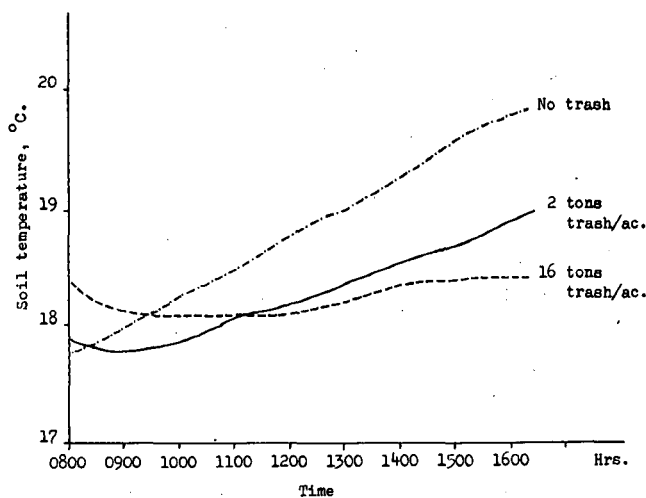


FIGURE 6 : Mean soil temperatures for three treatments at the 10 cm. depth in a Waldene series soil on 29/9/64

between the 2 tons and 16 tons of trash per acre treatments. The results at the 10 cm. depth shown in Figure 6 indicated that even the 2 tons trash per acre treatment conserved heat at this depth in excess of that conserved in the plot without trash.

It must be acknowledged that soil moisture conditions under the different treatments were inevitably different and that the additional heat capacity of the

moister soils under trash precluded any quantitative evaluation of the results in terms of an energy balance. Generalisations based on the data, even in terms of temperature effects, are therefore made with this reservation in mind.

The weather on 7th October, 1964, was warm with only intermittent cloud, and the clearly defined effects of five levels of trash mulch, compared with a control treatment without trash, under these conditions are shown in Figure 7 for the 5 cm. depth and in Figure 8 for the 10 cm. depth.

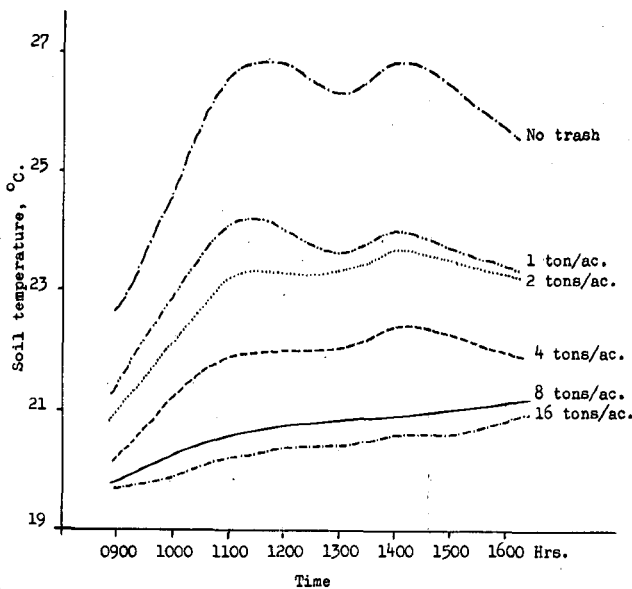


FIGURE 7 : Mean soil temperatures for six treatments at the 5 cm. depth in a Waldene series soil on 7/10/64

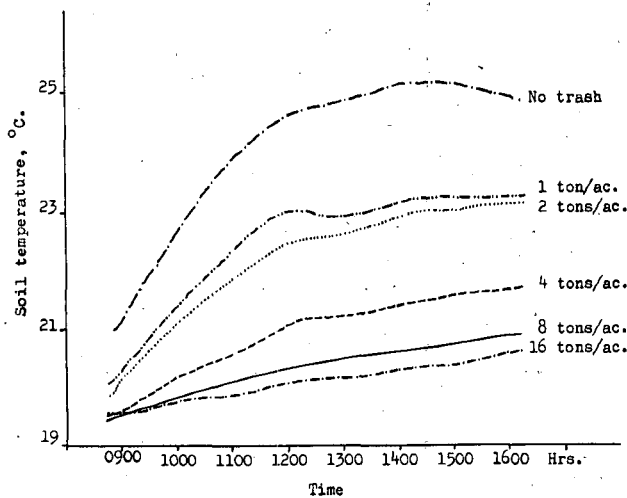


FIGURE 8 : Mean soil temperatures for six treatments at the 10 cm. depth in a Waldene series soil on 7/10/64

The collective results from this site on a Waldene series soil showed that the *post meridiem* decline in soil temperatures at shallow depths occurred earlier as the total insolation increased and the mean temperature rose, and that the decline was postponed by increasing amounts of trash mulch. In general it can be said that in the absence of a crop, the soil temperature in bare plots always rose above that in mulched plots during the day, even in midwinter, at the 5 cm. and 10 cm. depths. This was in contrast to data

obtained from Experiments I and III, on Rydalvale and Waldene soils respectively, where the presence of a crop canopy sometimes caused the reverse to be true.

Crop Nutrition

If a trash mulch increases crop yield by contributing to the nutritional status of the crop, an interaction between fertiliser and trash effects should be found. More particularly, the response to trash mulching compared with burning or removing the trash should be greater in the absence than in the presence of fertilisation. Further, if a nutrient derived from a trash mulch contributed to a positive response to the treatment, an increase in the amount of the particular nutrient in a plant indicator tissue might be expected.

The yield data for three crop cycles in Experiment I have been reported previously (Thompson, 1965). The mean response to trash mulching compared with burning over nine ratoon crops was 4.61 tons of cane per acre per annum in the absence of fertiliser and 4.06 tons of cane per acre per annum in the presence of fertiliser. Whilst these mean results might be construed as evidence of a slight nutritional effect of trash, the single instance in which a significant interaction was obtained, occurred under unusual conditions in the second ratoon stage of the third cycle. In this crop a severe drought caused excessive stalk mortality in the trashed, fertilised plots without a similar effect occurring in the trashed, unfertilised plots. This phenomenon was undoubtedly due to the much higher consumptive use of water in the fertilised treatment compared with the unfertilised treatment, and the results cannot therefore be regarded as direct nutritional effects. In fact, when the results for this crop are excluded from the mean data for Experiment I, the response to trash treatment appears to be slightly greater in the presence of fertilisation than in its absence.

In Experiment II the differences in yield between trash treatments (i) and (iii) represent the response to a trash blanket compared with burning and leaving the tops spread on the plots. The mean yield differences over seven ratoon crops for the three different fertiliser treatments were:

NP : 0.31 tons cane per acre per crop.

NPK : 1.18 tons cane per acre per crop.

NNPK : 0.61 tons cane per acre per crop.

The only occasion on which the interaction between trash and fertiliser treatments was significant was in the first ratoon stage of the second cycle, and the effect was the reverse of that required to indicate a nutritional contribution from trash. The comparisons of average data indicate, if anything, that trash improved the efficiency of potassium top dressings but not necessarily the nitrogen top dressings.

The design of the fertiliser treatments in Experiment III was based on the assumption that trash, being highly carbonaceous, would cause high C/N ratios to develop in the soil and consequently nitrogen deficiencies. No significant interactions between fertiliser and trash treatments occurred, but it was possible that the lower nitrogen level of 120 lb. N

per acre was sufficient alone to prevent any serious deficiency from developing. Table XII shows the mean responses to 7 tons of trash per acre compared with no trash (T2-T1), and also the mean responses to 25 tons of trash per acre compared with 7 tons per acre (T4-T2).

Table XII

Mean responses in tons of cane per acre to trash treatments at two levels of nitrogen in Experiment III

Crop	N1		N2	
	T2-T1	T4-T2	T2-T1	T4-T2
1R	-1.53	-2.05	9.83	-9.15
2R	7.87	1.37	10.00	0.98
2R	7.87	1.37	10.00	0.98
3R	6.10	2.51	9.70	-4.01
4R	2.26	-4.40	4.79	-2.53
Total	14.70	-2.57	34.32	-14.71
Mean/crop	3.67	-0.64	8.58	-3.68

The consistently greater response to trash at the higher level of N (240 lb. per acre) when comparing 7 tons of trash with no trash may be some indication that nitrogen nutrition was inadequate at 120 lb. N per acre to overcome the deleterious effect of a high C/N ratio in the shallow surface stratum of soil. The average results, when comparing the effects of 25 tons and 7 tons of trash per acre apparently warrant a different explanation since the trend was in the opposite direction. A depression in yield due to the higher amount of trash was on the average greater at the N2 level than at the N1 level. If the C/N ratio was a real consideration, therefore, it must have been relatively independent of the amount of trash mulch.

Leaf and sheath samples were taken from all of the plots in Experiment I at monthly intervals during the second ratoon crop of the third cycle. Sheath moisture levels for all treatments were in excess of 80 per cent on 9th April, 1962, and 11th March, 1963 when the crop was 9 months and 20 months old. On these dates it was found that third leaf nitrogen in samples from the trashed plots always exceeded that in burnt plot samples. In all instances but one the higher nitrogen levels in trashed treatments compared with corresponding burnt treatments were associated with higher tissue moisture contents. There must therefore be at least a suspicion that the apparent nitrogen effects were only indirect, being due not necessarily to better nutrition but to the better moisture conditions under trash.

No significant effects of trashing compared with burning were established for third leaf contents of P, K, Ca, Mg, Cu, Mn or Zn.

Discussion

It is generally agreed that adequate weed control in a ratoon can be effected with the trash from a crop of 40 tons of cane per acre. For varieties N:Co.376 and N:Co.382 this amounts to 6 or 7 tons of dry matter in trash per acre, and it is possible that the

same amount of trash could be obtained from as little as 30 tons of N:Co.310 per acre. The yield response to such a trash blanket, compared with burning, may amount to 4 tons of cane per acre per annum and it is due primarily to moisture conservation by a trash blanket (Thompson, 1965). In comparison with the considerable economic importance of ratoon weed control and soil moisture conservation, the effects of trash on the other soil properties studied and the nutrition of the succeeding crop must be of minor importance in the light of the experimental results reported here.

Soil and tissue analyses have confirmed that mineral elements are returned to the soil equally well whether burning or trashing is practised. The more gradual release from trash of nitrogen and other nutrients, contained in an average trash layer in quantities of practical significance, does not appear to cause any significant improvement of crop nutrition and yield. If nitrogen volatilisation is practically complete in a well-burned crop, it is difficult to understand how the 70 to 100 lb. of N per acre contained in the trash could fail to improve the yield of the succeeding crop if the trash were conserved. In this respect, the controlled burning of experimental plots may result in less N volatilisation than would occur in normal field-scale fires. In any event, the raking of the singed cane tops into a limited number of interrows, where they control weeds without interfering with the cultivation of the major part of the field, can be recommended in preference to the piling and reburning which is sometimes practised.

There is evidence to show that a trash blanket increases the efficiency of nitrogen and potassium top-dressings when compared with burning. This may be an indirect effect due to better moisture relationships in trashed areas, particularly as far as nitrogen is concerned.

The significant increase in the exchange capacity of soils under a trash blanket compared with those where cane is burnt derives almost certainly from organic colloids associated with the increased organic matter content. No advantage apparently accrues, however, in terms of additional adsorbed nutrient cations since the increase in exchange capacity is devoted entirely to hydrogen ions, causing a consistent decrease in the pH of soils permanently under a trash mulch.

Whilst the effects of trash on surface soil moisture characteristics were often statistically significant, these were quantitatively so small that they were unlikely to have been of importance in contributing to the moisture supply to the crop. On the Waldene series soil there could only have been a contribution if the soil moisture tension characteristics were improved by trash, since the increases in field capacity were always accompanied by increases in wilting point. Once again, this effect of trash was most probably associated with the increase in organic matter content of the soil.

Increases in the organic matter content of the soil have generally been found when the effects of organic mulches have been studied. Samuels *et al.* (1952) compared the soil from plots which had been burned

with that from plots where the trash had either been lined or buried. There were highly significant increases in soil organic matter content due to treatment with unburnt trash, the mean analytical results being 1.42, 1.82 and 1.70 per cent organic matter for the three treatments respectively.

Any practice which tends to increase the organic matter content of a soil must usually be advantageous but need not necessarily be economically warranted. In many areas of the cane belt burning is regularly practised, and it is therefore of interest to note the organic matter status of soils where the crops have been burnt for many years. In a Rydalvale clay loam the mean organic matter content in the surface foot of soil after 23 years of treatment was 7.65 per cent where the crop had been trashed continuously and 7.46 per cent where the crop had been burnt. In a Waldene fine sandy loam the mean results after 15 years were 2.67 per cent for the trashing treatment and 2.45 per cent for the burning treatment. A significant decrease in soil organic matter content due to burning therefore seems unlikely to have occurred, and an increase may well have occurred due to the large amounts of underground organic residues from each crop.

Although it is possible that the additional organic matter content of the soil under trash contributed to its greater water-stability of crumbs, the major factor in the surface 3 in. of soil was probably the physically protective action of a trash layer in preserving water-stability.

The effects of a mulch on soil temperature may obviously be complex, at times causing conditions to be cooler than in a bare soil, and at times causing conditions to be warmer. Under local conditions the main interest lies in the extent to which a trash layer causes soil temperatures in the root zone of sugarcane in winter to be lower than those in bare soil. It is possible that soil temperatures in winter become limiting to root growth and crop development, and it is an observed fact that a trash layer severely inhibits the ratooning of some sugarcane varieties in the high altitude areas.

According to Burr *et al.* (1957), root temperatures below 21° C were severely limiting to sugarcane growth in culture solutions. If these results can be applied to field soil conditions they may constitute a guide to the possibility of a mulch being deleterious to crop growth. Referring to Figure 4 it will be seen that at the 1 in. depth on the harvested plots, without a mulch, the soil temperature was always above 21° C at 3 p.m., but on the mulched plot soils this temperature was exceeded only from November onwards. In the unharvested plots, the critical temperature level was passed in early October in the unmulched soil, but not until mid-November in the mulched soil. The 8 a.m. results in Figure 3 show a lag of two months, from September to November, between the date on which the harvested, unmulched soil temperature exceeded 21° C and the date on which the harvested, mulched soil temperature did so. The comparable lag was only about one week in late November for the unharvested plot soil temperatures. Even at the 9 in. depth there were lags of about 2 months in the

8 a.m. and 3 p.m. data for the harvested plots, but only very small lags in the unharvested plots.

It is apparent that the possible effects of trash mulching on crop production through adverse soil temperature conditions take place early in the development of the crop in winter and early spring, and this is reflected in crop performance in these seasons in the high altitude areas.

Conclusions

Sugarcane varieties differ in the amounts of oven dry trash produced per ton of millable cane, and the ratio may also be affected by cultural treatment. Millable cane : oven dry trash ratios vary generally under local conditions between 5 and 7, but may rise even higher under irrigated conditions. The nutrient content of trash from 40 tons of N:Co.376 per acre is approximately 69 lb. N, 8 lb. P, 76 lb. K, 27 lb. Mg and 38 lb. Ca.

The nutritional contribution of a trash blanket to the succeeding crop is of no greater commercial importance than that following burning of the trash. Trash mulching affects both the field capacity and the wilting point of the soil but does not necessarily increase the total available moisture holding capacity of the soil. Increasing amounts of trash increase the amounts of organic matter in the soil progressively, and trash mulching increases the degree of water-stability in the soil crumb fraction greater than 0.5 mm. in diameter. A mulch does not affect soil bulk density or porosity significantly.

Trash tends to lower soil temperatures and to reduce diurnal soil temperature variations. Increasing amounts of trash cause greater effects, and in winter trash may cause higher soil temperatures, particularly in the early mornings, and to a greater extent in the presence of a crop leaf canopy.

Summary

The effects of trash mulching compared with burning on soil properties and crop nutrition were studied in three long-term experiments and several additional experiments. Trash production and the nutrient content of trash were measured in a growth analysis experiment.

For normally harvestable crops of cane the ratio of millable cane : oven dry trash lay between 5 : 1 and 7 : 1 and the nutrient content of the trash was approximately 69 lb. N, 8 lb. P and 76 lb. K per acre.

There were no detectable differences in available soil nutrients between samples from burnt plots and trashed plots even after 33 years of treatment. Tissue analysis confirmed that the nutritional effects were the same whether the trash was burned or conserved as an organic mulch. However, trash caused significant increases in soil organic matter, total exchange capacity, field capacity, wilting point and water-stability of soil crumbs greater than 0.5 mm. in

diameter. Trash did not change soil bulk density or porosity.

Soil temperatures were sometimes lower under trash than in a bare soil and sometimes higher, depending upon season, time of day, soil depth and the degree of crop canopy.

Acknowledgments

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Mr. du Toit (in the chair): With reference to Table IV I think that nitrification may be responsible for the drop in calcium and magnesium.

Mr. Hill: I would like to question Dr. Thompson on two points. Firstly, he has demonstrated very clearly that trash conservation increases the organic matter content of the soil and thereby the water-stability of the topsoil crumbs. Both of these characteristics should result in a decrease in soil bulk density, yet this is not shown to be the case. Did Dr. Thompson take the precaution of sampling for soil density at similar moisture contents? Soils containing appreciable quantities of 2:1 lattice clays change bulk densities with moisture content. Secondly, trashing is seen to increase the exchange capacity but decrease the percentage base saturation of a soil. Did Dr. Thompson notice any interaction with fertiliser in this respect?

Dr. Thompson: The base saturation data are available and I shall pass them on to you. The bulk density samples were probably equally wet at the time of sampling as it is our standard procedure to water a site prior to taking an undisturbed core.