THE INFLUENCE OF WATTLE-BRUSH BURNING ON CANE GROWTH

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ABSTRACT

Field and greenhouse studies have confirmed that wattle brush ash may cause marked increases in yield when sugarcane is grown in certain midland soils. This effect was associated with the following factors:

(i) decreased soil acidity
(ii) increased P and K uptake by the plant
(iii) increased soil exchangeable Ca, Mg, P, K and base saturation values
(iv) reduced soil levels of Al and Mn
(v) reduced concentrations of root Al.

Introduction

During 1968 an investigation was conducted in the Natal midlands to determine why sugarcane growing on sites where wattle brush had been burnt, produced better yields than cane grown in adjacent areas, where no burning had occurred. The typical difference in cane growth due to this effect is shown in Plate I.

The practice of burning forest litter and slash (brush) has been adversely criticised, mainly on the grounds that soil fertility is seriously impaired. Opinion generally however favours burning[2, 26] provided that soil temperatures are not raised unduly[11]. The effects on the soil of burning slash may be classified as:

(a) chemical
(b) physical, and
(c) biological

Austin[3] reports that burning results in the following chemical changes of the top soil:

(i) Reduction in soil acidity.
(ii) Large increases in nutrient availability, particularly in P, K, Ca and Mg.
(iii) Reduction in total nitrogen and organic matter.

Similar changes were noted by other workers,[1, 20] the extent of which depended on the nature of the brush burnt and the severity of the burn. These enhanced chemical effects on the soil have generally disappeared within 10 years of burning.[16, 25].

Physical effects such as increased percolation rate and macropore space have been observed by Tarrant,[23] following brush burning. Various workers have reported reductions in the population of soil microorganisms.[15, 19] Depending on the severity of the burn, fungi may disappear completely. Aerobic N fixers are apparently killed by burning but anaerobic N fixers survive.

Although the subject of veld burning in South Africa has received considerable attention,[10] little work has been published on the effects of burning brushwood

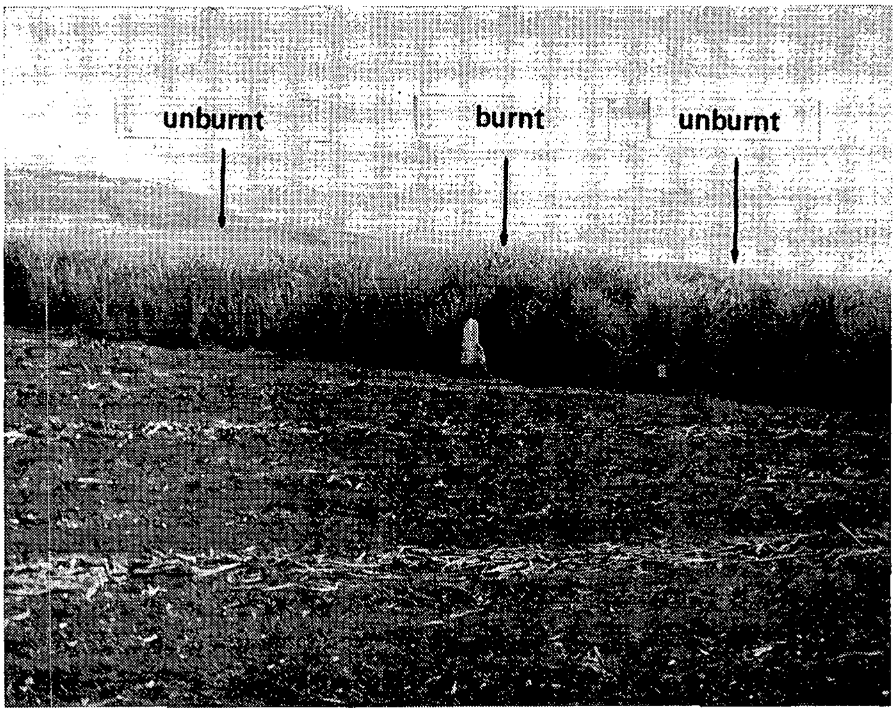

PLATE 1: Difference in cane growth due to wattle-brush burning (Windy Hill area).

on wattle soils. In experiments conducted on various plantation sites in Natal, Darby[11] showed that the burning of wattle brush resulted in significant increases in soil pH and exchangeable Ca. Soil temperatures rarely exceeded 112°C in the first 6 mm depth and the results he obtained indicate that the top 5 cm of the soil receive the greatest concentration of the heat liberated during the blaze. Measurements of soil structure and moisture retention on burnt and unburnt sites revealed no important differences.

Thompson[24] observed the lines characteristic of wattle brush burning traversing N.P.K. sugarcane trials at Wartburg. The difference in cane growth noted, suggested that the ash was supplying the soil with either a deficient nutrient(s), or that the burning had resulted in partial sterilization of the soil which proved beneficial to growth.

Black[6] harvested plant cane from burnt and unburnt lines in fields formerly under wattle at Seven Oaks and obtained the large differences in yield shown in Table I.

TABLE I
Average cane yield of three burnt and unburnt areas (metric tons/hectare)

Parent Material	Dolerite	Lower Ecca	% Ave. sucrose content
Burnt line	175	110	16.11
Unburnt line	77	59	15.03

In order to obtain some indication of the cause of these differences, the following studies were made.

Experimental

(1) *Field survey*

An intensive nutritional survey was carried out using soil and leaf samples collected from 20 sites where burning had occurred in the Seven Oaks, Windy Hill, Hilton and Eston areas.

Composite topsoil samples were taken from five 'good' and five 'poor' areas of growth, using a Beater sampler (30 cores per sample). Similarly composite third leaf samples were also collected at each site (30 leaves per sample).

The results of this survey are shown in Tables II and III for the soil and leaf material respectively.

Generally the burnt sites showed large increases in soil pH, total exchangeable bases and base saturation values, while marked decreases in exchangeable Al occurred. Most of these differences were significant at $P=0.05$. Leaf material from many of the burnt sites showed significant increases in per cent P and K and to a lesser extent in per cent Ca and Mg.

(2) *Greenhouse Experiments*

A series of pot experiments were carried out using topsoils representative of several midland series, namely, Balgowan (samples A and B), Balmoral and Trevanian.

Following a basic fertilizer dressing equivalent to 112 kg N and 112 kg K per hectare several replicates of the treatments shown in Table IV, were applied to the pots at the rates indicated.

Each pot was planted with a pre-germinated single-eyed cane sett, and the soil maintained at 60 per cent water holding capacity throughout the experiment. The cane was harvested after 16 weeks growth, tops, roots and soil being separated and prepared for analysis.

Wattle brush ash, plant material and soils were analysed by standard methods, with the exception of soil exchangeable Al which was determined by extraction with 0.2N NH_4OAc, using a modification of the procedure of Skeen and Sumner.[22]

Results

The most important results obtained from the pot experiments are given in Table V for the two Balgowan series soils. With the exception of (A) and (E) all the other treatments shown contained a dressing of single superphosphate equivalent to 1.12 tons/hectare (167 kgP/hectare).

The following effects were produced:

(i) significant yield responses (tops and stalks) due to the ash (I) and lime (H) treatments, amounting to (+20%) and (+14%) respectively for the Balgowan (A) and (+48%) and (+19%) respectively for the Balgowan (B) soils. Similar trends were obtained for the stalk (shown in Plate 2) and root yields.

(ii) a significant reduction in yield due to the Al treatment (O), of (-90%) and (-60%) for the two soils respectively. Severe chlorotic symptoms were observed in the foliage and the root system showed signs of the restricted coralloid development described by Evans[12] for cane affected by Al toxicity.

(iii) substantial reductions in yield following sterilization (D) for both the soils (See Table V). However, the Trevanian series soil (not shown) produced some response to this treatment.

(iv) significant, positive changes in the plant uptake of P, K, Ca and Si from the superphosphate (C), ash (I) and basic slag (E) treatments. Ash in particular caused large increases of P and K and also produced marked decreases in the concentrations of Mn in the tops, and of Al in the roots.

(v) significant increases in soil pH from below 4.5 to between 5.2 and 5.6 due to the ash and lime treatments. There was also an increase in base saturation values from about 10 per cent to over 40 per cent following these treatments.

(vi) significant increases in the P, K, Mg, Si and Ca status of the soil due to the ash treatment.

(vii) significant reductions in soil exchangeable Al due to the ash, lime and basic slag treatments.

Discussion

Various plant-soil relationships will now be examined in order to pinpoint some of the factors responsible for the yield increases due to the wattle ash.

TABLE II
Analysis of soils sampled from burnt and unburnt areas

Parent Material	L Ecca shale (Seven Oaks)			M. Ecca shale (Hilton)			T.M.S. (Eston)			T.M.S. (Bruyns Hill)		
Soil Properties	burnt	unburnt	difference*	burnt	unburnt	difference	burnt	unburnt	difference	burnt	unburnt	difference
% Clay	66	68	NS	61	61	NS	22	19	NS	39	41	NS
% Organic matter	5.3	5.5	NS	5.0	5.5	NS	5.5	5.6	NS	3.0	3.5	NS
pH (water)	5.10	4.30	S	4.70	4.26	S	5.5	4.54	S	4.80	4.50	NS
S-value (meq %)	6.20	1.35	S	2.08	0.95	S	5.90	2.30	S	1.52	1.04	NS
C.E.C. (meq %)	14.4	14.6	NS	12.5	12.7	NS	7.4	7.4	NS	8.2	8.5	NS
% Base stn.	43	9	S	16	7.5	S	74	31	S	18	12	NS
P (ppm)	32	3	S	10	5	NS	22	18	NS	12	9	NS
Al (ppm)	145	760	S	280	610	S	22	230	S	272	320	NS

* S denotes the difference is significant (P=0.05) NS denotes the difference is non significant.

TABLE III
Leaf analysis of cane from burnt and unburnt areas

Plant Composition	Seven Oaks			Hilton			Eston			Bruyns Hill		
	burnt	unburnt	difference	burnt	unburnt	difference	burnt	unburnt	difference	burnt	unburnt	difference
% N	2.13	1.71	S	2.32	2.27	NS	2.30	2.26	NS	2.19	2.25	NS
% P	0.40	0.23	S	0.22	0.21	NS	0.18	0.12	S	0.15	0.14	NS
%K	2.70	1.36	S	1.39	1.35	NS	1.63	1.21	S	1.64	1.25	S
% Ca	0.79	0.28	S	0.37	0.32	NS	0.33	0.54	S	0.17	0.13	NS
%Mg	0.61	0.41	S	0.37	0.29	NS	0.55	0.70	S	0.30	0.25	NS
Fe (ppm)	1000	740	S	370	460	NS	230	350	NS	234	340	NS
Al (ppm)	340	550	S	350	570	S	220	280	NS	382	470	NS
Mn (ppm)	77	70	NS	46	116	S	66	80	NS	77	42	NS
Zn (ppm)	18	15	NS	26	16	S	18	21	NS	8	11	NS

TABLE IV

Treatments used in pot experiments (tons/hectare)

Treatments	No.	P	ash	lime ($CaCO_3$)	basic slag	Si (Na_2SiO_3)	Al ($AlCl_3$)
Control (N + K)	A	—	—	—	—	—	—
Single supers (denoted as P).	C	0.167	—	—	—	—	—
Sterilisation + P	D	0.167	—	—	—	—	—
Sterilisation + P + ash	G	0.167	18.0	—	—	—	—
Basic slag	E	—	—	—	9.0	—	—
Ash	J	—	18.0	—	—	—	—
Ash + P	I	0.167	18.0	—	—	—	—
Al + P	O	0.167	—	—	—	—	1.12
Al + P + ash	M	0.167	18.0	—	—	—	1.12
Lime	B	—	—	9.0	—	—	—
Lime + P	H	0.167	—	9.0	—	—	—
Lime + P + ash	F	0.167	18.0	9.0	—	—	—
Si	N	—	—	—	—	0.112	—
Si + P	L	0.167	—	—	—	0.112	—
Si + P + ash	K	0.167	18.0	—	—	0.112	—

(*a*) *Soil pH and Yield*

The highest yields were obtained when the soil pH values were between 5.2 and 5.6, as shown by the relationship in Fig. 1. The effect is shown in Table V by the greater yield obtained when superphosphate and lime were used (H, pH>5.0) compared with that when superphosphate was used alone (C, pH<4.50).

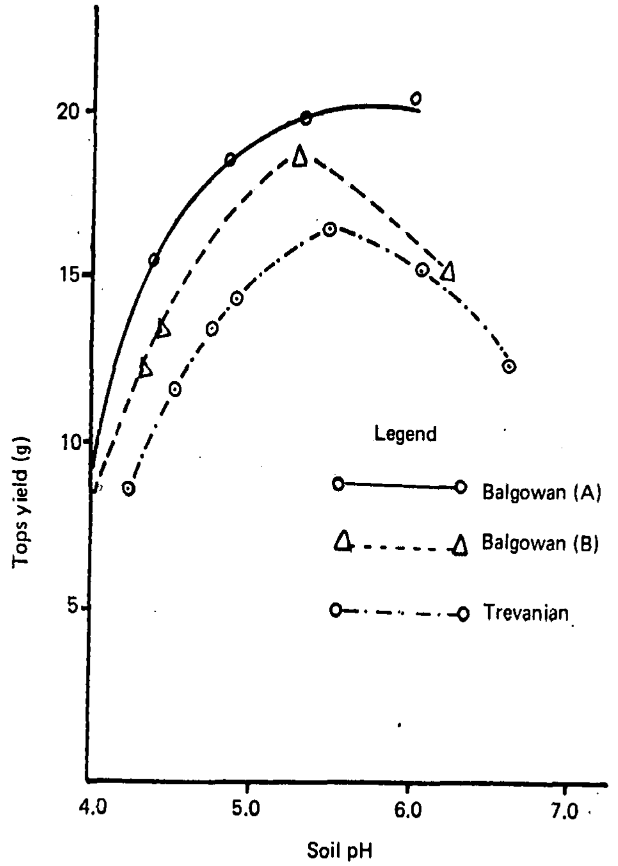

FIGURE 1: Relationship between cane yield and soil pH.

(*b*) *Yield in Relation to P Uptake*

The additional P from the ash (2—3% P_2O_5, as shown in Table VI) raised the P status of the soil resulting in a linear increase in the P uptake as yields increased. ($r_{tops}=0.89$, $r_{stalk}=0.81$). This is shown in Fig. 2.

Earlier it was shown that lime improved yields when the soil pH values were raised above 5.0. This increased yield was associated with an increased uptake of P when compared with the superphosphate only treatment (C). As lime does not contain P, the additional P taken up can only have resulted from the

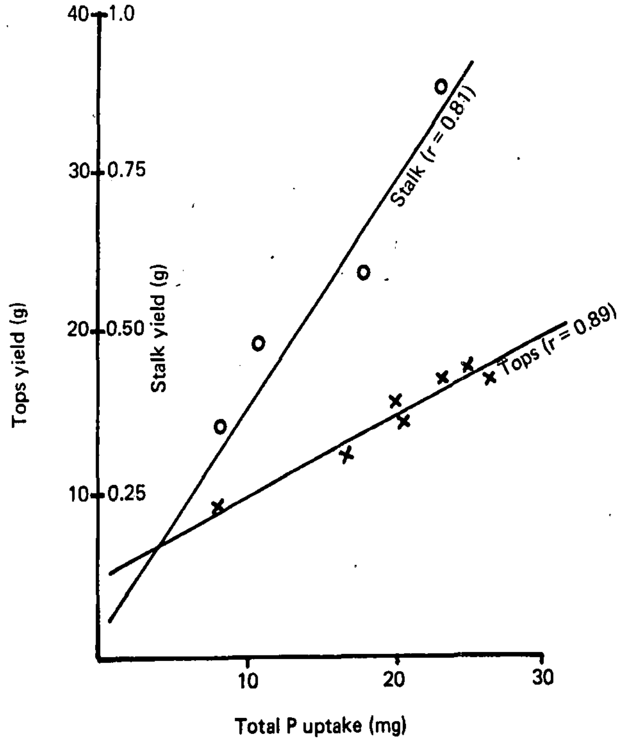

FIGURE 2: Yield in relation to P uptake.

TABLE V
Cane yield, soil and plant analysis following the addition of various treatments to two Balgowan soils

Soil	Selected Treatments	No.	Yield Tops + stalk g	% diff relative to C	Root yield g	SOIL ANALYSIS pH (H_2O)	Ex Al ppm	P ppm	K ppm	S-value (meq %)	% Base Satn.	LEAF ANALYSIS P mg	K mg	Mn ppm	Root % Al
BALGOWAN (A)	Control (N & K)	A	10.4	-39	1.5	4.15	810	6	47	0.95	8.1	11.5	177	265	1.32
	Supers (single)	C	16.8	0	2.8	4.43	644	18	54	1.21	8.4	22.0	171	485	1.51
	Sterilisation	D	12.0	-29	1.2	4.93	311	27	95	2.47	25.9	12.1	204	573	1.01
	Basic slag	E	17.5	+4.2	4.6	4.80	390	15	39	1.68	13.3	22.1	146	560	0.96
	Ash	I	20.0	+20	3.9	5.50	67	39	86	11.91	55.8	32.9	458	205	0.62
	Lime	H	19.2	+14	4.2	5.20	132	16	34	8.24	46.6	27.4	182	282	0.85
	Aluminium	O	2.0	-90	0.2	3.70	1342	32	185	2.18	16.7	—	—	—	—
	Al and Ash	M	10.8	-36	1.0	4.60	556	46	310	12.74	75.9	19.1	313	376	1:02
	Silicon	L	15.4	-8.3	2.5	4.72	521	20	62	1.82	11.0	21.6	210	407	0.65
	L.S.D. (P=0.05)		2 40	—	1.40	0.23	168	9	23	1.61	7.0	6.3	4.5	118	0.18
BALGOWAN (B)	Control (N& K)	A	8.1	-36	1.7	4.10	770	3	36	0.97	12.4	5.5	111	326	—
	Supers (single)	C	12.8	0	2.5	4.20	610	14	33	1.40	15.6	16.9	109	386	—
	Sterilisation	D	8.2	-36	1.2	4.40	383	17	120	1.50	24.8	5.7	127	653	—
	Basic slag	E	13.4	+4.7	2.2	5.20	320	11	34	2.20	24.1	19.6	133	186	—
	Ash	I	19.2	+48	4.2	5.25	100	30	82	8.92	63.6	25.5	314	186	—
	Lime	H	15.2	+19	2.9	5.00	120	15	33	7.25	56.7	19.8	118	230	—
	Aluminium	O	4.2	-66	0.4	3.70	1270	22	57	1.91	23.1	5.9	85	182	—
	Al & Ash	M	11.5	-10	1.2	5.70	124	41	120	9.32	68.3	19.6	307	342	—
	Silicon	L	15.0	+17	3.1	4.70	455	16	39	1.66	11.5	20.1	132	380	—
	L.S.D. (P=0.05)		1.06	—	1.30	0.25	67	10	32	0.35	3.70	4.9	34	54	—

TABLE VI
Range in Chemical Composition of Wattle Ash

Constituent in ash	CaO	SiO_2	K_2O	MgO	Al_2O_3	Fe_2O_3	P_2O_5	MnO
% Range in composition of three ash samples	35—45	10—15	8—11	6—10	2—4	2—3	2—3	1—3

pH range of a (10 : 1) aqueous solution, 9.80 - 10.40

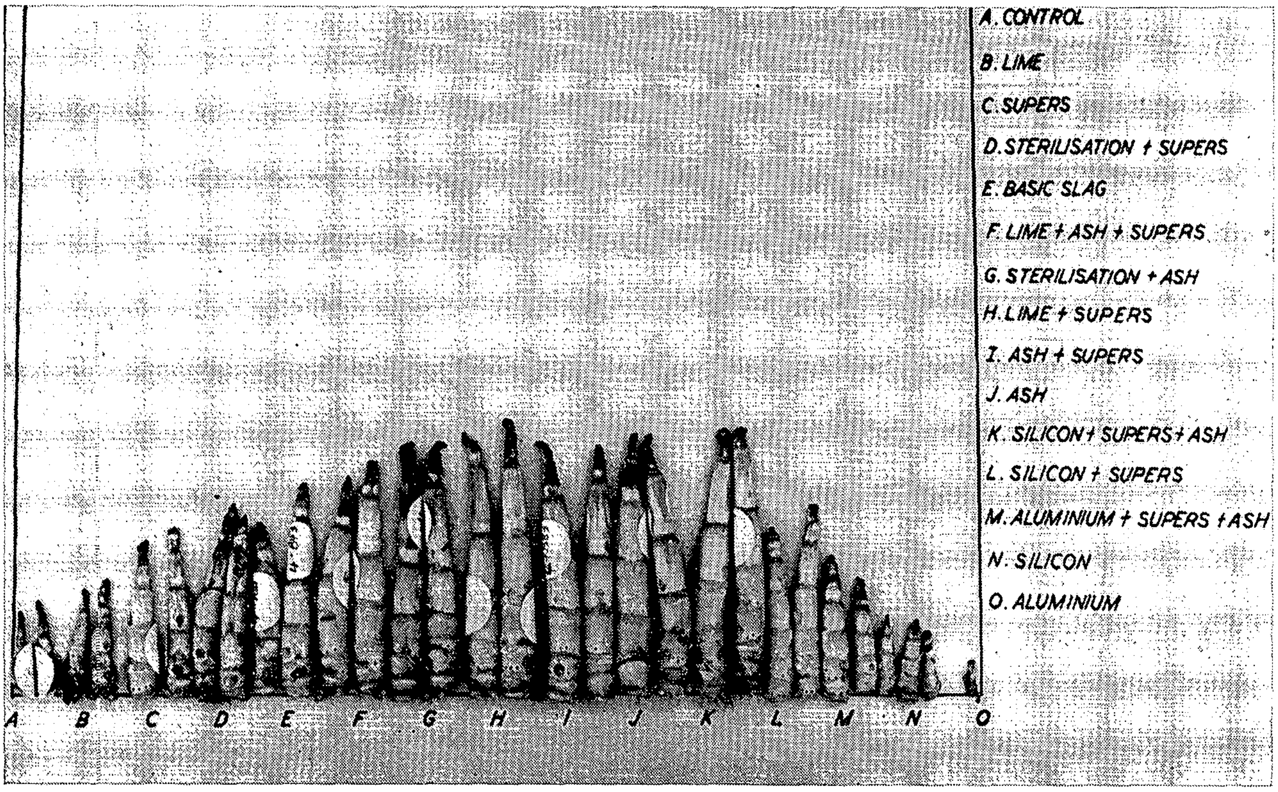

PLATE 2: Stalk growth on the Balgowan A soil as affected by various amendments.

effect of lime on the factor(s) responsible for P fixation in the soil and plant roots.

The higher yields obtained due to ash compared with lime, may similarly have been due to a reduction in the factor(s) responsible for P fixation, although the P present in the ash must also have been contributory. The question of P fixation in the soil and roots will be considered later.

(c) *Yield in Relation to Exchangeable Al*

The improved yields associated with the ash treatments may also be examined in the light of the exchangeable Al in the soil. Results from the field survey (Table II) showed that soils containing the ash in burnt areas had Al values generally below 500 ppm.

Table V confirms that the ash reduced high concentrations of exchangeable Al by more than 90 per cent in the case of the Balgowan (A) soil, and to a marked extent in the other Balgowan soil.

Fig. 3 shows how increasing Al levels from sample to sample retarded growth considerably. Generally optimum yields were associated with exchangeable Al values below 300 ppm. Slope differences between the regression lines indicate that yields on the Balgowan soils were more sensitive to changes in Al levels compared with yields on the Balmoral soil. This may have been due to the higher levels of exchangeable Al in the Balgowan soils (810 ppm and 770 ppm respectively) compared with the Balmoral soil (302 ppm).

Plate 3 provides evidence that a differential yield response in relation to exchangeable Al content existed even between the two Balgowan soils. The addition of Al to the Balgowan (A) soil (810 ppm) was clearly more detrimental to cane growth than the same amount of Al applied to the Balgowan (B) soil which had a lower exchangeable Al value of 770 ppm.

Likewise the addition of ash also showed a larger

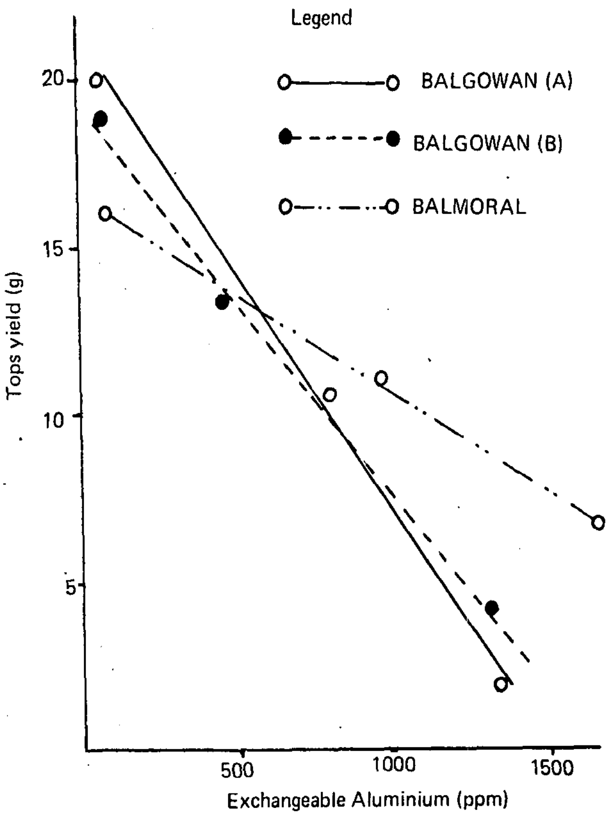

FIGURE 3: Yield in relation to soil exchangeable Al.

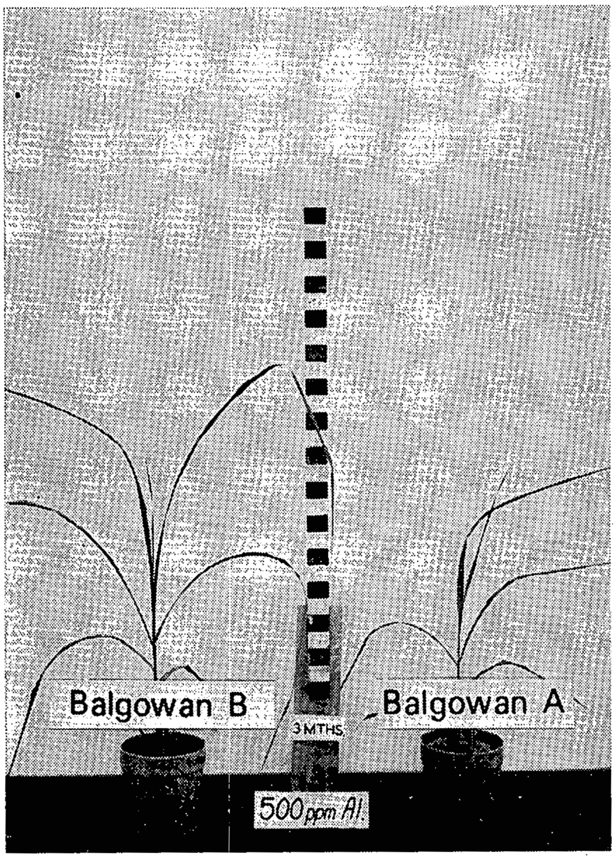

PLATE 3: Cane growth on Balgowan soils to which Al was added.

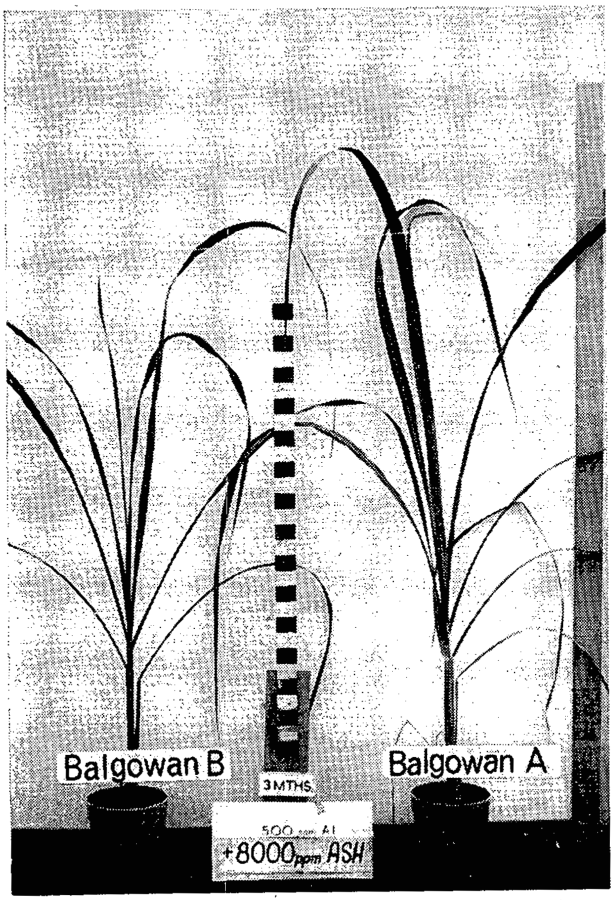

PLATE 4: Cane growth on Balgowan soils to which Al and wattle-brush ash were added.

positive effect on the (A) soil than on the (B) soil as shown in Plate 4. These findings suggest that the higher the exchangeable Al in the soil the greater is the likely response to ash. provided that other soil nutrient(s) are not limiting. An explanation based only on pH seems unlikely as both soils showed pH values of 4.10 ± 0.05.

The effect of lime on stalk and root yield, and the Al status of the soil was found to be similar in some respects to the effects of ash. Fig. 4 illustrates the response obtained at various levels of exchangeable Al and clearly shows that a direct relationship exists for the soils used.

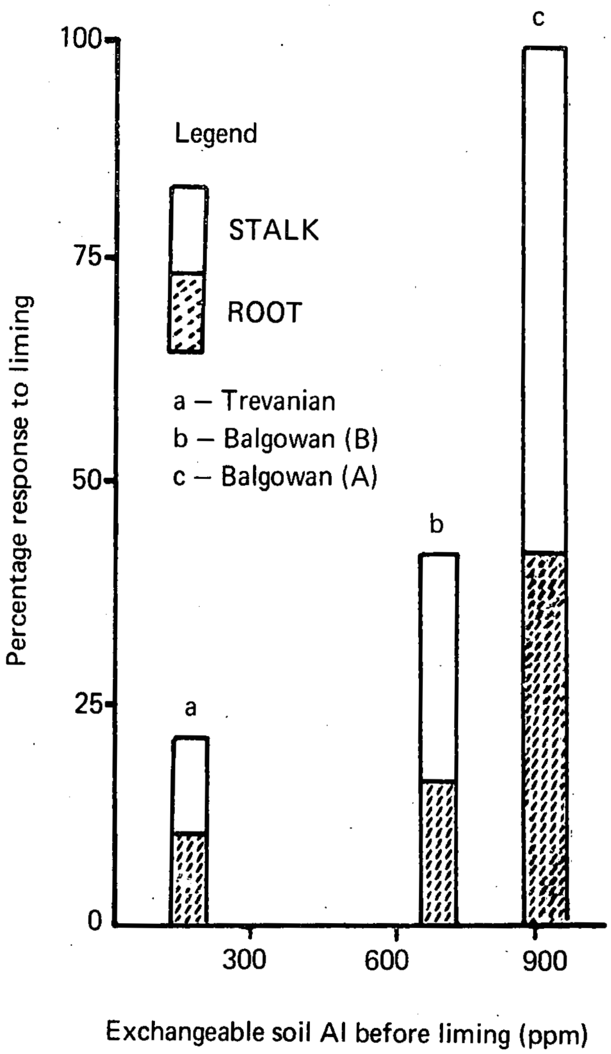

FIGURE 4: Response to liming in relation to the Al status of three soils.

These considerations imply that on the sites without ash, the high exchangeable Al contents of the soil (greater than 500 ppm) may have been toxic to cane growth.

Fig. 5 indicates that root yield was reduced to a greater extent than top yield with increasing exchangeable Al in the soil. This agrees with the results obtained by Foy and Brown[14] for other crops. Clarkson[8] similarly found that root growth was quickly affected when plants were presented with toxic amounts of Al, whereas top growth was only influenced later.

Table V also shows that when exchangeable soil Al

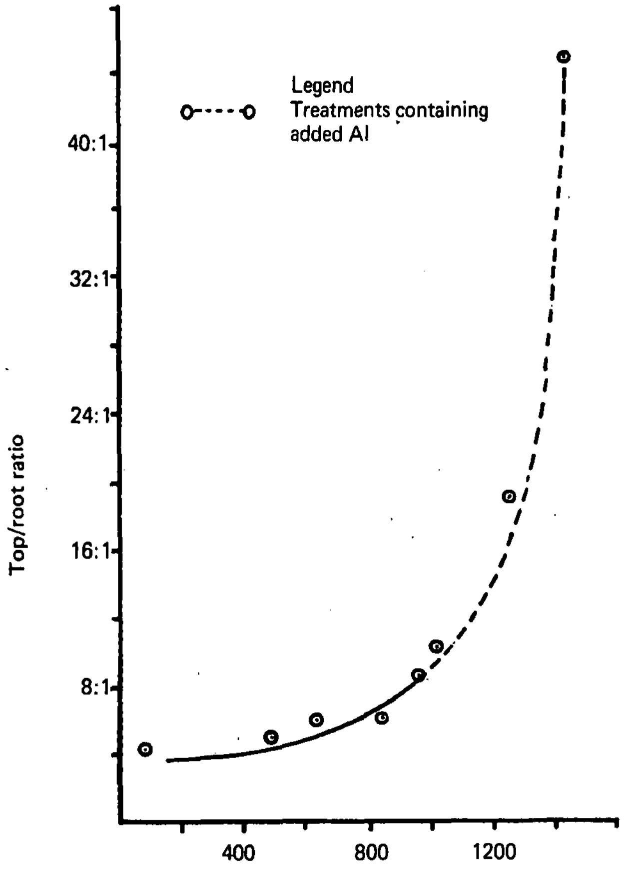

FIGURE 5: Influence of exchangeable soil Al on cane top/root ratio.

exceeded 500 ppm, the concentration of root Al generally exceeded one per cent and the associated root yields were just over half the yields obtained from the ash, lime or basic slag treatments.

The data are not presented here, but soil Al soluble in NKCl amounted to nearly 60 per cent of the exchange capacity (C.E.C.) of some of the soils from unburnt sites. Based on the criterion established by Evans for sugarcane (cited by Ayres[4]) that Al values in excess of 60 per cent of the C.E.C. result in growth failure, there is an implication that the soils studied in the present investigation are in the marginally toxic category.

(*d*) *P Uptake in Relation to Soil and Root Al*

Apart from the direct physiological effect that Al has on the cells of the root tissues, [13], [18], [21] the relationship shown in Fig. 6 indicates that high soil Al was associated with considerably reduced P uptake by the plant.

Macleod and Jackson[17] found that Al in the roots precipitated significant amounts of P, thereby reducing the P taken up by the rest of the plant. In view of the high Al concentrations in the roots (>1 %) from plants in treatments (A) and (C) (shown in Table V), it is possible that a similar mechanism involving the immobilization of the nutrient P by root Al was operative in these treatments, which closely resemble the soil conditions of unburnt sites.

For soils from burnt sites, however, ash considerably reduced the exchangeable Al in the soil and also the concentration of Al in the roots (shown by treatment I, Table V). This may account for part of the significant increase obtained in the P uptake in this treatment.

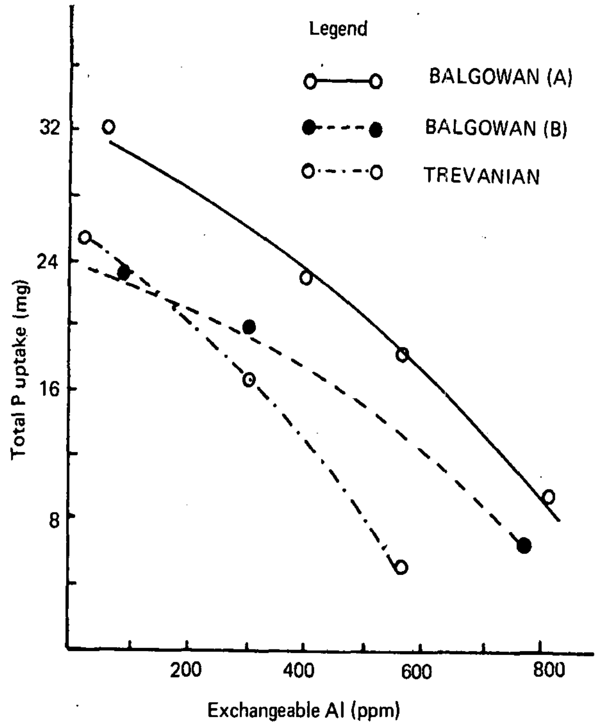

FIGURE 6: P uptake in relation to exchangeable soil Al.

The rise of soil pH to a value above 5.0 due to the ash treatment may also have contributed to the increased uptake of P by the cane plant, following the precipitation of soluble Al, which is responsible for fixing small quantities of P at pH values below 5.0[7].

(*e*) *Yield and K Uptake*

Table V shows that there was more than a twofold increase in the uptake of K where ash was present (except treatment M) compared with treatments without ash. This was due to the fairly high potassium content of the ash (Table VI) which likewise more than doubled the K status of the soils used.

Fig. 7 illustrates how the concentration of tops K varied with the nature of the applied amendments. Applications of ash produced leaf concentrations of more than 2 per cent K compared with approximately 1 per cent in the superphosphate (C) and lime (H) treatments. The K : Ca ratios varied from 6 : 1 in treatments with ash to 2 : 1 in treatments with superphosphate and/or lime. Based on results obtained by Bishop[5], K : Ca ratios of between 5 : 1 to 6 : 1 are about the average values for cane harvested under field conditions.

These results suggest that under conditions of heavy superphosphate and lime application a reduced uptake of K may result due to the luxury uptake of Ca from the $CaSO_4$ and $CaCO_3$ in these materials. This would agree with the findings of Clements[9] who reported that excessive Ca uptake may be accompanied by inadequate K uptake.

The significant difference in yield between the ash

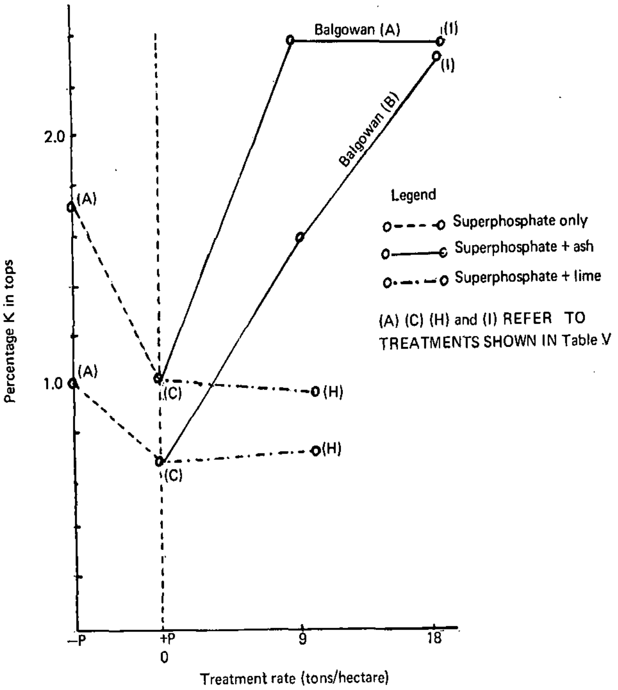

FIGURE 7: K concentration of tops in relation to superphosphate, ash and lime treatments on Balgowan A and B soils.

(G) and lime (M) treatments on the Balgowan B soil may have been partly due to the additional K in the ash restoring the K : Ca ratios to satisfactory levels of 6 : 1.

(f) Other Factors

No further important plant-soil relationships could be established from the results obtained. Ash did tend to increase the Si uptake and reduce the Mn concentration in the tops for two of the soils studied. There was insufficient evidence, however, to determine whether these changes affected cane yield.

Due to the high silica content of the ash (>10%) a response to Si could not be discounted.

Summary and Conclusions

The main beneficial effects of wattle ash on cane growth may be summarised as follows:

(i) Significant increases in tops, stalk and root yield.

(ii) Neutralization of soil acidity with optimum yields occurring between pH values of 5.2 and 5.6.

(iii) Reduction of soluble and exchangeable Al which probably reduced both P fixation and toxic effects in the roots.

(iv) Reduction of the concentration of root Al resulting in an increase in the utilization of P by the plant and a more balanced top/root ratio.

(v) A source of readily available P and K taken up by the plant over and above the amounts added in the basic dressing.

(vi) Restoring the K : Ca nutritional balance as shown by an increase in the leaf K : Ca ratio from about 2 : 1 to 6 : 1.

(vii) A source of Si which may be utilized if this nutrient becomes limiting.

No single factor was found to be common for all the soils studied. At some of the sites the difference in cane yields may have been due to a straightforward deficiency, as for example K and Si in some of the sandier acid soils derived from Table Mountain Sandstone or Dwyka Tillite.

Elsewhere, particularly on midlands mistbelt soils derived from Lower and Middle Ecca sediments (which show high P fixation) the present evidence indicates that ash has a threefold effect on the P utilization of the plant. P is not only supplied directly from the ash but also indirectly by reducing the concentration of soluble soil Al and root Al, which has the effect of making more P available to the plant.

The solution to the problem on the acid soils in the midlands will lie in using an ameliorant, or combination of ameliorants, that will simulate the beneficial effects produced by the wattle ash. Lime by itself does not provide the entire answer. Finely ground siliceous slags and filter press seem to be better alternatives and these are at present being tested in the field at Seven Oaks. Preliminary estimations of yield appear to be favourable.

Acknowledgements

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Discussion

Mr. du Toit (in the chair): In Figure 5 we are not indicating a better growth of tops with increased aluminium but rather a very poor root growth.

Dr. Hill: In Table VI the pH of the wattle ash solution is high and no mention is made of sodium content.

Is it high in sodium, and what effect would sodium have on aluminium in the soil?

Mr. Meyer: The sodium oxide content was low — about 1 to 2 per cent.

The reason for the high pH is due to the presence of large concentrations of calcium oxide and potassium oxide in the ash.

Professor Sumner: Sodium carbonate or sodium hydroxide will have an effect on aluminium but will spoil the soil.

Dr. MacVicar: Wattle brush has the effect of increasing yield. In trying to match this we treat the land in various ways.

We overcome some of the problem with aluminium, but not all.

Mr. du Preez mentions a possible additional effect of silica.

May not phosphate fixation also play a role?

For example, at Shongweni, there is a marked effect from wattle brush burning on soils that do not have any aluminium at all but have fixed phosphate.

What is the effect of phosphate fixation and reduction of aluminium toxicity?

Professor Sumner: These are unrelated problems.

Aluminium toxicity is not present in all soils but in ferralitic soils in the Midlands phosphate fixation is invariably found. There is no point in applying heavy doses of phosphate unless you increase the pH to such an extent that the aluminium is eliminated. Thereafter, for quite large applications of phosphate a linear response is obtained. But the response to phosphate is poor if it is added without taking care of the aluminium.

We have not found phosphate more available as the result of adding lime except in so far as the lime has removed aluminium toxicity.

Mr. Meyer: Results from the pot experiments have shown that a lime dressing improves the amount of P assimilated by the plant. This implies that P availability in soils of below pH 5.2 is increased due to the elimination of soluble Al which is one of the factors responsible for the fixation of P, as insoluble aluminium phosphate, as far as we know. The other more predominant P fixation factors such as the hydrous oxides of Al and Fe are not affected by liming and will therefore not contribute towards the increased P uptake.

Mr. du Preez: It has been found overseas that massive applications of phosphate will also reduce aluminium concentration in soils.

Mr. Gilfillan: Could we not achieve our object by ploughing in gypsum? Its greater solubility might offset the uneven distribution.

Professor Sumner: I am at present gathering evidence about this which I hope to present at the Congress next year.

Gypsum's efficacy depends on the use of water with it — it must have a large amount of water and this involves economic consideration.

Dr. Hill: What is the mechanism of aluminium removal?

Professor Sumner: By lime it is:—

$Al+3OH=Al\,(OH)_3$

By gypsum it is:—

Clay Al+CaSo4=Clay Ca+Al

Mr. Odendaal: Is there an easy method to determine if aluminium is the problem?

Also, is there a scale, of either lime or gypsum, for various levels of aluminium, exchangeable calcium or possibly pH?

Professor Sumner: When referring to any of the series we have been discussing today, if the pH in water is above 5.4 you are safe.

The critical level in 0.01M calcium chloride, which I prefer, is pH 4.8.

The break starts between 4.8 and 4.6, and below 4.6 there is definitely aluminium.

On sands an application of between 1,000 and 3,000 kg of lime per hectare 15 cm is necessary.

On heavy soils you can go up to 8,000 kg.

Mr. Odendaal: Is calcium carbonate more efficient than calcium sulphate?

Professor Sumner: For this reaction it is much more efficient but for the leaching reaction the gypsum is better.

I would like to ask Mr. Meyer what the roots looked like in the bad treatments.

Mr. Meyer: The roots produced by treatments other than ash or lime were generally stunted, thickened, red in colour and with a restricted development of secondary roots in contrast to the thinner, lighter and greater proliferation of branch roots in the healthy root systems, obtained from the ash and lime treatments.

Mr. Cougnet: Has manganese toxicity as such been identified?

Mr. du Preez: From our experiments it was not possible to determine exactly whether there was a manganese or an aluminium toxicity. Both are highly dependent on pH.

However, evidence is mainly in favour of aluminium and not manganese toxicity.

Professor Sumner: Manganese is a problem if the soil is flooded. But in our soils it is aluminium and not manganese.