POTASSIUM IN SUGARCANE PRODUCTION

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Abstract

The amount of potassium fertilizer used in the sugar industry has increased dramatically during the past 25 years, due partly to the increase in area under sugarcane but also to large increases in the amount of K fertilizer applied per hectare. Correlations established between soil and leaf analysis, and crop response to potash are discussed, and also the effect of potassium on cane quality. It is concluded that while soil and leaf analysis can be used to provide a fairly accurate assessment of K required for sugarcane, certain anomalies exist which emphasise the need for an improvement in the reliability of our soil test K recommendations.

Introduction

The potassium requirement of sugarcane is high under South African conditions, estimated nutrient removal by a 100 t/ha cane crop, being 90 kg K as compared to 60 kg N and 18 kg P. According to Innes (1959) nearly 80% of the potassium removed in a cane crop can be found in the final molasses and is lost to the soil. The actual amount of potassium removed is determined by the extent to which potassium in the soil meets the demand for this element by the crop. If growing conditions are favourable and potassium is freely available to the crop, sugarcane will take up more than its essential requirement of the nutrient. This surplus absorption by the plant is known as 'luxury consumption' and is quite commonplace in sugarcane production.

Innes (1959) has stated that the ability of the soil to maintain the necessary minimum activity of potassium depends upon the rate of uptake of potassium by the plant, the potash in the form of unweathered or partly weathered minerals, the rate at which these release potassium, the proportion of the element lost due to fixation by clay minerals and by drainage, the nature of the soil exchange complex, and the balance between additions from fertilizer and removal by the crop. Stewart (1969) has referred to the relative importance of soil cations other than potassium. Although the correct balance of cations cannot be accurately defined, it is nevertheless certain that a close relationship exists between potassium, calcium and magnesium and that an excess or a deficiency of any one affects the uptake of the others.

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Amounts of potassium fertilizer used

The potassium fertilizer used almost exclusively in the South African Sugar Industry is muriate of potash and this is the case in many other cane growing countries. The need for increased amounts of potassium fertilizer in many areas of the cane belt was first indicated by du Toit (1951). About this time potassium deficiency symptoms began to appear in many fields thus discounting the general belief that most soils of the industry contained adequate amounts of naturally available potassium for continuous sugarcane production.

Total fertilizer usage

Since 1951 there have been dramatic increases in the amounts of potassic fertilizer used in the sugar industry. This is apparent from the data given in Table 1, from which it may be seen that between 1951 and 1974 there was a fourteen-fold increase in the amount of nitrogen fertilizer used, but over a fortyfour-fold increase in potash usage.

TABLE 1 Amounts fertilizer nitrogen and potassium used in the South African Sugar Industry from 1951 to 1974

Year	N in metric tons	K in metric tons	N kg/t cane harvested	K kg/t cane harvested
1951	1936	634	0,44	0,15
1952*	–	–	–	–
1953	3018	1289	0,53	0,23
1954	4097	2118	0,61	0,32
1955	5313	3436	0,73	0,47
1956	6711	4356	0,98	0,64
1957	6237	5564	0,80	0,71
1958	9221	8957	0,99	0,96
1959	10273	9578	1,24	1,16
1960	6662	5880	0,85	0,75
1961	4269	4511	0,50	0,53
1962	5967	5415	0,61	0,56
1963	15500	14564	1,56	1,47
1964	17720	18405	1,66	1,73
1965	17710	16197	2,11	1,93
1966	17213	14318	1,22	1,02
1967	18088	16629	1,07	0,96
1968	19585	17237	1,43	1,26
1969*	–	–	–	–
1970*	–	–	–	–
1971*	–	–	–	–
1972	23129	22654	1,37	1,35
1973	27684	27080	1,79	1,75
1974	26993	28077	1,60	1,66

*data not available for these years.

TABLE 2 *Crop production and mean yields in the South African Industry from 1951 to 1974*

	Sugarcane Harvested (metric tons)	Total area under cane (ha)	Mean yield* metric tons/ha
1950	–	176 293	–
1951	4 359 250	170 948	24,7
1952	5 191 441	185 821	30,4
1953	5 644 080	213 253	30,4
1954	6 689 801	215 926	31,4
1955	7 262 914	227 606	33,6
1956	6 834 162	231 782	30,0
1957	7 796 909	239 522	33,6
1958	9 305 791	249 292	38,9
1959	8 276 607	256 492	33,2
1960	7 846 803	257 878	30,6
1961	8 513 106	257 630	33,0
1962	9 751 248	246 419	37,8
1963	9 939 528	249 657	40,3
1964	10 661 268	291 248	42,7
1965	8 406 273	326 966	28,9
1966	14 102 760	338 543	43,1
1967	16 913 450	336 672	50,0
1968	13 719 694	330 731	40,8
1969	14 787 860	330 295	44,7
1970	12 143 897	330 429	36,8
1971	16 751 114	319 425	50,7
1972	16 804 645	316 427	52,6
1973	15 453 687	322 858	48,8
1974	16 895 335	337 813	52,3
1975	16 813 531	–	–

* Yields refer to sugarcane harvested per hectare under cane during the previous year.

Thompson (1968) noted that the amounts of N and K in fertilizers used annually showed a progressive increase from 1951 to 1959, but restricted sugarcane production in 1960 – 1962, resulted in an immediate decrease of fertilizers used during this 3 year period. Smaller decreases in fertilizer use were due to various factors such as a severe summer drought in 1965, and the fluctuating world sugar price.

Amounts used per hectare and per ton of cane produced.

The total area under cane in each year from 1951 – 1974 is shown in Table 2. Between 1951 and 1966 it can be seen that there was almost a 100 per cent increase over this 16 year period. The mean amounts of N and K in fertilizers used annually per hectare are shown in Figure 1. There was a consistent increase in K fertilizer used per hectare from 1951 – 1959, followed by a marked decrease during the period of restricted production. Maximum K and N fertilization per hectare however occurred during 1963 and 1964, which reflects the larger planting programmes and expansion taking place at the time (Thompson, 1968).

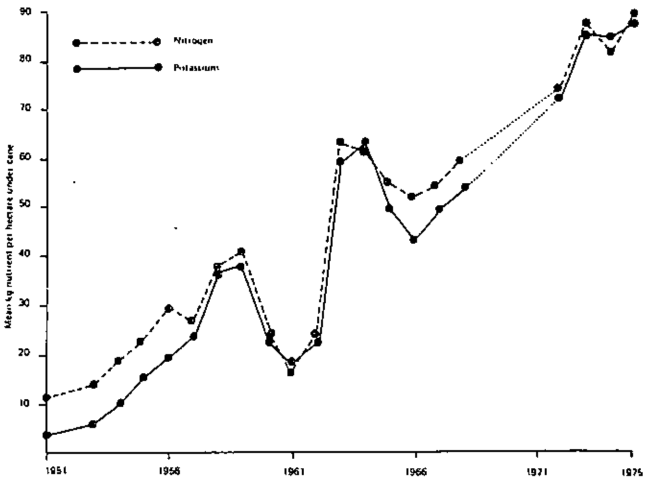

FIG 1 *Mean amounts of nitrogen and potassium fertilizers used annually per hectare under cane*

It is interesting to note that since 1957 the mean amounts of N and K fertilizers used annually per hectare have been roughly equivalent.

Economics of increased fertilization

Comparing mean yields for four successive periods between 1951 and 1974, in relation to the mean amounts of fertilizer N and K used, the mean yield increases have more than justified the additional fertilizer costs for successive periods (Table 3).

In fact the net value of a metric ton of cane/ha or even less would have covered the cost of additional fertilizer, which implies that the increased cost of fertilization over the past 24 years has been economically warranted.

TABLE 3 *Mean cane yields in relation to mean amounts of fertilizer N & K used (1951 – 1974)*

Period	N	K	Mean yield/annum
	(kg per hectare)		metric tons/ha
1951 – 1956 (excl. 1952)	19,4	10,7	30,0
1957 – 1962	28,3	26,5	34,4
1963 – 1968	56,8	52,3	41,0
1969 – 1974	79,6	79,5	47,7

More recently however there have been indications that too much nitrogenous and potassic fertilizer are being applied in some areas. At the end of 1974 a comprehensive survey was undertaken of the S A S A Experiment Station Fertilizer Advisory Service recommendations made to cane growers in respect of N, P and K for the years 1971 – 74 inclusive (Wood, 1975). The prime objective of the survey was to ascertain which N–P–K mixture or mixtures would have been recommended most frequently (other than 4:1:6) had they been available, as it was feared that application of this mixture was leading in many instances to inefficient and uneconomical use of potassium.

The results of the survey indicated that there was over-fertilization with potassium to a considerable extent in most areas of the industry and that a mixture such as 6:1:7 would be more appropriate. The need for a change in ratio of some fertilizer mixtures was discussed with the major fertilizer companies, and as a result the mixture 5:1:5 was offered as a substitute for 4:1:6, rather than a 6:1:7 mixture which would have been difficult to manufacture or store. The new mixture was introduced in 1976 and should result in a considerable saving in expenditure on potash fertilizer within the sugar industry.

The response of cane to potash

Since 1950 more than 100 fertilizer trials have been conducted throughout the cane belt, largely by the Sugar Experiment Station, and the results have been correlated with soil and leaf analyses in order to assess crop fertilizer requirements.

The importance of potash was demonstrated experimentally by the inauguration in 1950 of a series of 3x3x3 NPK trials which added much to our knowledge of sugarcane nutrition in Natal. The standard K treatment levels in these trials were 0/93 and 186 kg K/ha. In 1956 the above trials were supplemented by a more ambitious series of 4x2x3 NPK experiments in which the ratoon crops received 0/140 and 280 kg K/ha. Jointly these two sets of trials covered virtually all existing soil and climatic conditions of the industry, though other trials were conducted to measure the effects of four levels of applications of potassium ranging from 0 to 336 kg K/ha.

The results of this work have been reported in detail by Stewart (1969). Briefly, statistically significant increases in yield are unlikely to be obtained from applications of fertilizer providing more than 110 kg K/ha, although there are situations where a good response can be obtained from rates up to 220 kg/ha, particularly when applied to soils derived from Table Mountain Sandstone (TMS) and granite. Subsequently, nutrient surveys conducted by Alexander (1967) and Meyer *et al* (1971) have confirmed that extensive potassium deficiency exists in TMS-derived soils. Responses to potassic fertilizers were found to increase progressively in succeeding ratoons.

For many sugarcane growing countries the normal potash dressing ranges between 83 and 166 kg K/ha. This is approximately the same range as for fertilizer nitrogen, which is in accordance with Stewart's opinion (1969), that a 1:1 N/K ratio is rather close to the average requirement of the cane plant, and emphasises the general suitability of the 5:1:5 NPK fertilizer mixture recently introduced into the industry, as well as the 1:0:1 mixture which has been used for many years.

Soil and leaf analysis and crop response to potassium

In South Africa as well as many other countries a reasonable correlation has been established between soil analytical data and sugarcane crop response. In an unpublished paper, Bishop (1967) discussed the reliability of predicting yield responses to potassic fertilizers based on soil analysis and yield results for the 3x3x3 and 4x2x3 factorial trials previously mentioned. Using a soil threshold value of 125 ppm K he concluded that responses to potassium would have been predicted correctly in 74 per cent of the experiments, incorrectly in 16 per cent, while predictions for the remaining 10 per cent would have been of doubtful value.

However, soil threshold values for exchangeable K, found in other cane growing areas are generally somewhat lower than the 125 ppm K that was used until a few years ago in South Africa. In the West Indies, Hardy and Rodrigues (1949) reported values of 65 ppm in sands and loams and 95 ppm K in clays and silts. Humbert (1963) said that consistent responses could be expected in Hawaii when K levels fell below 75 ppm K, while above 100 ppm K there was little likelihood of significant responses to potassic fertilizers. In the Phillipines, Locsin *et al* (1956) obtained marked responses below 95 ppm K, and variable responses between 95–120 ppm K. Currently the critical value used by the Fertilizer Advisory Service is 112 ppm K based on analysis of a 1N ammonium acetate extract.

In the South African Sugar Industry leaf analysis (based on the central portion of the top visible dewlap or third leaf, less midrib) has played a most useful part in potash nutrition as discussed by du Toit (1959). It is in fact considered to be potentially a more reliable measure of potash deficiency than soil analysis. Du Toit states that when the level of K in the third leaf falls below 1% on a dry matter basis potash responses can generally be expected. Between 1,0% and 1,25% K responses are variable and above 1,25% K they are unlikely. For some years now our critical value for leaf potassium has been 1,05% . Evans (1965), however, states that as potassium is all extractable by water from the cane tissues, the expression of its level in terms of dry matter can be misleading, and that the moisture content of the leaf should first be determined. However in South Africa it is not considered worthwhile to take leaf samples under conditions of moisture stress.

TABLE 4 The preparation of whole cycle K fertilizer recommendations based on soil analysis

SOIL–K LEVEL	K (ppm)	> 290	245	200	160	112	100	90	75	67	56	< 45
	K (kg/ha)	> 650	550	450	350	250	225	200	175	150	125	<100
	KCl (kg/ha)	over 1300	1100	900	700	500	450	400	350	300	250	<200
Fertilizer requirements (kg/ha)	Plant cane K / KCl	Nil	Nil	Nil	Nil	75 / 150	100 / 200	125 / 250	150 / 300	175 / 350	200 / 400	225 / 450
	1st ratoon K / KCl	Nil	Nil	Nil	Nil							
	2nd ratoon K / KCl	Nil	Nil	Nil								
	3rd ratoon K / KCl	Nil	Nil			125 K 250 Potassium chloride			150 K 300 Potassium chloride			
	4th ratoon K / KCl	Nil										

Notes: **Plant cane** Where the K requirement exceeds 150 kg/ha up to a maximum of 225 kg/ha, a split application of potash is recommended, half in the furrow at planting, and half top-dressed 8 – 10 weeks after planting. This is particularly appropriate for sandy soils of the Cartref, Fernwood and Clansthal series where leaching is a problem.

Ratoons A single broadcast application soon after harvest is recommended for all soils, up to a maximum of 175 kg K/ha.

Soil and leaf analysis are considered to be complementary, and this approach has been emphasised by the introduction of whole cycle fertilizer advice into the industry a few years ago. In this system soil analysis is limited to a comprehensive pre-plant sample taken after ploughout from which fertilizer recommendations are given for the plant crop and four succeeding ratoons. Leaf analysis during each ratoon can then be used as a check on the adequacy of the recommendations given. Standards for the preparation of whole cycle K recommendations are given in Table 4.

Potassium and cane quality

Potash deficiency not only reduces the yield of cane but also lowers juice quality. Without adequate potassium the plant photosynthesises more slowly and respires more rapidly, and movement of newly formed sugars from the leaves to the storage tissues in the stalk is restricted. Du Toit (1960) showed that decrease in sugar content under the influence of high nitrogen application is greatly aggravated by potassium deficiency, as seen in Table 5.

It may be seen that increasing N application in the absence of potash causes a decline in sucrose content, whilst the addition of potash largely restores it, resulting in excellent sucrose responses to potash at high N levels. It should be emphasised, however, that increase in sucrose content due to potash application is largely a function of potash yield response and no increase in sucrose content may be expected where the potash status of the crop is satisfactory.

Innes (1959) states that since yield response to potash treatment tends to result in a reduction in the tissue concentration of other elements, the improvement in juice quality could be interpreted as resulting from a reduction in the nitrogen concentration of the tissues. Foliar analyses from British Guiana reported by Evans (1955) supported this view, for where the addition of potash was not reflected in a reduction of leaf N, it did not improve cane quality, whilst quality was improved when potash application brought a reduction in leaf level of N.

TABLE 5 The interaction between potassium and nitrogen in terms of sucrose per cent cane (5^2 factorial trial)

kg K per hectare	kg N per hectare					
	0	110	220	330	440	Mean
0	17,34*	16,56	16,18	15,84	15,72	16,33
93	16,98	18,26	17,30	16,31	16,38	17,04
186	17,28	17,25	17,59	17,18	17,60	17,38
279	18,08	17,45	17,66	17,66	17,10	17,59
372	17,44	17,64	17,10	17,02	17,37	17,32
Mean	17,43	17,44	17,17	16,80	16,83	17,13

* Sucrose per cent cane values

Problems in predicting cane potassium requirement

Meyer *et al* (1971) in a nutrient survey of the sugar industry reported that there was often poor agreement between leaf K values and the corresponding soil exchangeable K values. More than 18% of leaf samples showed marginal to low K values whilst the corresponding soil sample had adequate to high levels of exchangeable K. A recent re-examination of the data by Burrows (1975) using the present threshold values of 1,05% K for leaf and 112 ppm K for soil, showed that 31% of leaf samples taken from can grown on soils derived from Lower Ecca Shales, and 45% from the doleritic soils of the Nkwaleni Valley and alluvial soils of the Monzi area, still showed this anomalous effect. Meyer *et al* considered that 2:1 lattice clays and possibly K fixation were responsible for the anomaly. Subsequently similar anomalies have been observed on 5 month-old cane sampled in October and November on several estates in Swaziland, where many of the soils exhibit high levels of calcium and magnesium, suggesting possible antagonistic effects to potassium uptake. Evans (1959) comments that antagonism is very marked in certain areas of British Guiana, which are affected by a potassium deficiency which is induced by high soil magnesium levels. There has also been evidence of poor correlation between exchangeable K and yield in a very precise fertilizer trial conducted on irrigated cane at Pongola.

In a recent paper Skogley (1976) reports that in the United States and Canada problems have arisen in regard to determining how much potassium should be applied to fields. When soil tests showed medium to very high amounts of available K, additional potash applied to these fields improved yields 25% of the time, and for some crops up to 80% of the time. It is believed that the problem is related to climate and how this influences potassium uptake. Leverington *et al* (1962) in Queensland have shown that the available potassium in Queensland soils (determined by leaching with 0,2N HC1) varies, often as much as three fold, and according to the time of year at which soil samples are collected. They recommend a standardised procedure to eliminate seasonal variation.

The physical state of the soil may make the interpretation of soil analysis results extremely difficult. Differences in uptake of potassium by sugarcane under various soil physical conditions were demonstrated by Hare (1962). He showed how increasing moisture in a well aerated soil increased K uptake, whilst water-logging decreased it, and was associated with low foliar potassium indices. Other factors such as the effects of soil drying on K release, movement of nutrient ions into clay lattices, antagonism between ions in the soil solution may all result in inadequate mineral nutrition of the cane plant.

Preliminary studies have indicated that the soils of the South African industry vary in their capacity to buffer levels of available potassium when this nutrient is progressively removed by cropping. It would seem therefore that a measure of the long term ability of our soils to supply available K may be of considerable importance, particularly as it relates to our potash recommendations in whole cycle fertilizer advice. Currently a programme of work is being undertaken to examine some of the problems mentioned above.

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