SUGAR CANE NUTRITION AND FERTILIZER USE IN SOUTH AFRICA

R.A. Wood
South African Sugar Association Experiment Station,
Mount Edgecombe, South Africa

Key words: Sugarcane, soil analysis, leaf analysis, fertilizer

ABSTRACT

In South Africa during the past four decades considerable research has taken place on the nutrient requirements of sugarcane. Consequently marked changes have occurred in patterns of fertilizer use. The value of N, P and K fertilizers for cane production is reviewed using field experimental data. Correlations established between soil and leaf analysis and crop responses to various nutrients are discussed. Fertilizer recommendations based on soil and leaf analyses have provided a useful guide for determining the nutrient requirements of cane. Several soil factors affecting plant nutrient availability will make it necessary to revise periodically the current system of recommendations.

INTRODUCTION

Since 1950 revolutionary changes have occurred in fertilizer use for sugarcane production in South Africa. During this period the nutritional requirements of sugarcane have been the subject of a large amount of field, laboratory and glasshouse experimentation by the South African Sugar Association Experiment Station, which has sought to develop soil and leaf analyses as a basis for fertilizer advice.

FERTILIZER USE

Sugarcane in South Africa is presently grown on about 400 000 hectares. Fig 1 shows that the annual average yield of cane has doubled over the past 30 years and this, to a considerable extent, is due to a significant increase in the amount of fertilizer used by the sugar industry. However, the increase in mean yield over this period has more than justified any additional fertilizer costs (Meyer and Wood16). The changing patterns in fertilizer use are illustrated in Fig 2, which shows the average amounts of N, P and K used annually per hectare cane between 1951 and 1987. While the area under cane increased by a factor 2.3 during this period, the amounts of nutrients used increased approximately as follows: N by a factor of 18, P by a factor of 3 and K by a factor of 42.

THE RESPONSE OF SUGAR CANE TO N P K FERTILIZERS

Early work

Thompson25 pointed out that, for the first 70 years of its development, the South African sugar industry lacked any rational solution to the problem of crop nutrition, but from the 1920's onwards a more scientific approach began to develop. In 1926 the newly established Experiment Station started replicated trials in which the merits of N P K and green manure treatments were tested. These early trials gave good economic responses to P (Dodds and Fowlie1, Lintner8) but responses to N and K were disappointing. However, in subsequent experiments (Lintner7, Watson26) some excellent responses to 250 kg K/ha were obtained.
Figure 1. Average yield of sugarcane (tons/ha/a) between 1951 and 1985.

Figure 2. Amounts of N, P and K used per hectare under cane 1951-1987.

Exploratory and regional fertilizer trials

Undoubtedly the most important phase that added significantly to knowledge of sugarcane nutrition under local conditions was the establishment by the Experiment Station in 1950 of thirty-one 3X3X3X N P K exploratory trials. In 1956 these trials were superseded by a more comprehensive series of fifty-three 4X2X3 NPK regional fertilizer trials (RFT). Generally the results reported by du Toit showed economic responses to N and K fertilizers at levels far higher than those in use at the time, and assisted greatly
in the development of rational fertilizer programmes. By correlating soil and leaf analytical data with the yield responses obtained from these trials it was possible to provide minimum or threshold levels of nutrients required for optimum cane growth on a wide range of sugar industry soils. These threshold values and others shown in Tables 1 and 2 formed the basis of the Fertilizer Advisory Service (FAS) established by the South African Sugar Association in 1954, and which operates today from the Experiment Station. Over the years, as results from more recent fertilizer trials have become available, considerable advances have been made both in the scope and type of fertilizer recommendations given to cane growers.

### Table 1 - Soil threshold values currently used by FAS.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Threshold</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus (P)</td>
<td>31 ppm (70 kg/ha)</td>
<td>for plant cane</td>
</tr>
<tr>
<td></td>
<td>11 ppm (30 kg/ha)</td>
<td>for ratoons</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>112 ppm (250 kg/ha)</td>
<td>clay content 30% or less</td>
</tr>
<tr>
<td></td>
<td>150 ppm (340 kg/ha)</td>
<td>clay content more than 30%</td>
</tr>
<tr>
<td></td>
<td>225 ppm (500 kg/ha)</td>
<td>&gt; 40% clay (irrigated areas)</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>150 ppm (340 kg/ha)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 ppm (225 kg/ha)</td>
<td>only on Recent sands of marine origin</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>25 ppm (60 kg/ha)</td>
<td></td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>1.5 ppm</td>
<td>those soils from the Midlands area where lime in excess of 3 tons/ha is recommended</td>
</tr>
<tr>
<td></td>
<td>1.0 ppm</td>
<td>clay content more than 15%</td>
</tr>
<tr>
<td></td>
<td>0.5 ppm</td>
<td>clay content 15% or less</td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td>20 ppm</td>
<td></td>
</tr>
<tr>
<td>Lime</td>
<td>When Al &gt; 80 ppm (clay more than 35%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>or &gt; 54 ppm (clay 15 to 35%)</td>
<td></td>
</tr>
</tbody>
</table>
| | or > 27 ppm (clay less than 15%) | (These values relate to analytical results obtained from samples taken prior to fertilizer application)

Note: 1 part per million (pprm) is equivalent to 2.25 kg/ha.

### NITROGEN

The mean responses of sugarcane to applied N in all the N P K exploratory and RFT trials conducted since 1950 were reviewed by Wood39. He showed that, based on previous studies (Wood9, 20) it was possible to relate N fertilizer responses in both plant and ratoon crops, to the N mineralization capacity of the soil on which an experiment was conducted. Results of a series of fertilizer trials conducted in the Natal Midlands on acid humic soils, showed that the amounts of N applied to ratoon cane on these soils could be greatly reduced, whilst cane yields and quality were improved (Moberly et al2). Wood3 reported that enhanced mineralization of N following liming of these soils, could be a factor contributing to a reduction in the sucrose content of cane.

Since 1977 data from comprehensive laboratory studies, and more than 40 N/K fertilizer trials have resulted in an improved system of N recommendations for plant and ratoon cane (Meyer et al19, 20). Optimum levels of N for ratoon cane determined from response curves were found to be inversely related to soil organic matter content and soil N release, both for rainfed and irrigated cane as shown in Fig 3, N recommenda-
Table 2 - Leaf threshold values currently used by FAS

<table>
<thead>
<tr>
<th>Nitrogen Area</th>
<th>Crop age</th>
<th>Month of sampling</th>
<th>Plant</th>
<th>Ratoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>3 to 5</td>
<td>Oct to Dec</td>
<td>1.9</td>
<td>1.8</td>
</tr>
<tr>
<td>irrigated</td>
<td>months</td>
<td>Jan to Feb</td>
<td>1.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mar to Apr</td>
<td>1.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Coast</td>
<td>*4 to 7</td>
<td>Nov to Dec</td>
<td>1.9</td>
<td>1.8</td>
</tr>
<tr>
<td>lowlands</td>
<td>months</td>
<td>Jan to Feb</td>
<td>1.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>March</td>
<td>1.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Midlands</td>
<td>*4 to 9</td>
<td>Nov to Dec</td>
<td>1.9</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>months</td>
<td>Jan to Feb</td>
<td>1.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>March</td>
<td>1.7</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Other nutrients:
- P: 0.19%  Ca: 0.15%  S: 0.12%  Cu: 3 ppm
- K: 1.05%  MG: 0.08%  Zn: 13 ppm  Mn: 15 ppm

The values given above are for third leaf samples taken from vigorously growing cane.

* In the case of summer cut ratoon cane it may be possible to sample when the crop is only three months old. For plant cane, sampling will normally only be possible when the crop is five to six months old.

Trations for plant and ratoon cane are now based on soil form, bioclimatic region, and the capacity of the soil to release N to the plant. For advisory purposes soils have been classified into four categories (low, medium, high and very high) according to their potential to mineralize N from soil organic matter. By this method rationalization of N fertilizer recommendations has already resulted in considerable savings for many growers.

**PHOSPHORUS**

Trials on P-fixing soils
Since the early 1970’s research based on P adsorption isotherm measurements, glasshouse studies and field trials has shown that increased P fertilizer applications are economically justified on certain high P-fixing soils in the Natal Midlands (Meyer13). In 1974 and 1975 six P fertilizer trials were established on soils which provided a satisfactory range of combinations of extractable P and P-fixing capacity. Yield results of the plant and first ratoon crops showed that combined broadcast and in-furrow placement of P fertilizer, applied at planting, was generally more effective than the conventional in-furrow P application alone, since the advantage of high P availability during the early stages of crop growth was coupled with that of a large volume of soil in which roots could have access to available P during later stages of growth (Meyer and Dicks14).

Soil tests for measuring available soil and P-fixation
In order to assess the implications of the P-fixing capacity of soils in the Natal Midlands, the accuracy of predicting a response to a broadcast application of superphosphate was further improved by supplementing the modified Truog method for soil available P using 0.02 N sulphuric acid (du Toit et al15), with a rapid phosphorus desorption index (PDI) method, developed by Reeve and Sumner23, to measure the P fixation capacity.
R.A. WOOD

(Meyer\textsuperscript{9}). The technique has been used routinely on an advisory basis for the past decade and soils are classified into strongly, moderately and weakly P-fixing categories, and the P fertilizer recommendations are adjusted accordingly. As phosphatic fertilizers have been applied for many years in the South African sugar industry there has been an appreciable build up of available P in many soils, apart from those where P fixation is a problem. Based on a recent survey of 2,000 fields by Hulbert\textsuperscript{6}, only about 13% of them would have required additional P fertilizer for ratoon cane while 42% would have required no additional P at time of planting. It is believed that in many areas of the industry substantial reductions in P fertilizer costs can be achieved without detriment to yield.

Factors affecting P availability

Several soil factors which can influence the correct prediction of P fertilizer requirement for cane were reported by Meyer and Wood\textsuperscript{17}, and current research is concerned with three of them. There is now sufficient evidence based on comprehensive laboratory and glasshouse studies to indicate that strongly P-fixing soils outside the traditional Midlands areas occur more widely than was previously thought. Field trials are in progress to confirm whether extra P fertilizer is required when cane is grown on moderate to strongly P-fixing soils in areas other than the Natal Midlands.

Results from glasshouse trials have indicated that fertilizer P applied to strongly P-fixing soils is not irretrievably lost due to P retention by the soil. At least 20% of the applied P mainly in the Al-bound form, was used efficiently by succeeding ratoon crops and up to 35% in moderately P-fixing soils. In view of these significant residual effects it is possible that the amount of P recommended as a top-dressing on P-fixing soils could be reduced, but further work is first required.

Analysis of slightly alkaline alluvial soils, taken from cane areas in Natal which have been subjected to past and recent flooding, has indicated that they are adequately supplied with available P as measured by the Truog extraction procedure but leaf analysis has indicated the opposite. In the glasshouse, both sorghum and sugarcane showed a marked growth response when fertilizer P was applied to several of these soils. Investigations are continuing, before the introduction of a correction factor to compensate for the Truog P value or the replacement of this method with one more suited to soils with high pH values.

POTASSIUM

The mean responses of sugarcane to applied K in the N P K exploratory and RFT trials were reviewed by Stewart\textsuperscript{24} and Wood\textsuperscript{31}. Results of a 1970 industry-wide nutrient survey (Meyer \textit{et al.}\textsuperscript{18}) revealed that 44% of the 487 leaf samples analyzed were K deficient, as were 40% of the 487 soil samples. Consequently, more than 70 further K trials have been conducted.

Soil analysis and crop response to K

The threshold value used for K by the Fertilizer Advisory Service was 112 ppm for all soils until 1982, when it was modified to accommodate soil texture following results from glasshouse trials (Wood and Burrows\textsuperscript{34}) and re-assessment of early, and of the more recent fertilizer trials (Meyer and Wood\textsuperscript{16}). The average responses to applied K from more than 100 trials were classified according to three soil textural categories and arranged in decreasing order of exchangeable K. On light to medium textured soils the
majority of responses to applied K were significant and coincided with pre-treatment soil K levels below 112 ppm K. Responses on heavier textured soils, however, were variable and not well correlated with pre-treatment soil K levels, many significant responses being associated with soil levels of exchangeable K ranging from 112 to 549 ppm K. An interim threshold value of 150 ppm was therefore introduced for soils with a clay content of more than 30%. However, recent results mainly from irrigated N/K fertilizer trials confirmed that 150 ppm K was not adequate for soils with more than 40% clay with melanic and heavy red orthic A horizons in which 2:1 lattice clays predominate. A threshold value of 225 ppm K was recently introduced to cater for this category of soils in the northern irrigated cane areas.

Factors affecting K availability

Several soil factors that can markedly influence the availability of K to sugarcane were discussed in detail by Wood and Meyer, and current research is concerned with three of them. The apparent suppression of K uptake observed in winter cut cane growing on the highly Ca/Mg saturated soils of the northern irrigated areas is being actively investigated. Despite seemingly adequate levels of exchangeable soil K, nutrient imbalance in the soil solution is thought to be causing uptake of excessive amounts of Ca and Mg relative to K, because the supply or release rate of K from the soil is insufficient. Additional Ca and Mg ions are needed to maintain electrical neutrality in the soil solution. Although non-exchangeable K reserves have been assessed for the majority of sugar industry soils, it has not yet been possible to determine satisfactorily the rate at which these reserves are released from the interlayers of clay minerals in the soil.
in order to replenish K in equilibrium with the soil solution. A promising extraction technique which characterizes K release from clay interlayers is being evaluated. In recent N/K trials some of the largest responses to applied K were obtained on strongly K-fixing soils with vertic A horizons, and an exchangeable K content of approximately 350 ppm. A higher threshold value of about 300 ppm K is thus indicated on these soils. Further K trials are being conducted on vertic soils to determine the effects of K fixation on optimum rate of applied K.

OTHER NUTRIENTS

Zinc (Zn) deficiency, aluminium (Al) toxicity and sulphur(S)

Although minor element deficiencies are infrequent in the South African sugar industry, zinc deficiency which was first reported by du Toit has been a continuing problem. A routine soil test procedure was developed by Meyer and, in conjunction with glasshouse and field trials, threshold values for Zn were established in both soil and leaf samples (see Tables 1 and 2). Field and glasshouse studies also revealed that Al toxicity was prevalent in many soils of the Natal Midlands. A modified exchangeable aluminium index (EAI) method proved to be very effective in establishing the degree of Al toxicity present in the soil (Moberly and Meyer). The relationship between EAI and clay content is used on a routine basis for predicting the toxic effects of Al in soil thus establishing its lime requirement (see Table 1). Recent laboratory and glasshouse studies in conjunction with several field trials have emphasized the importance of S deficiency as a factor which could limit cane growth. Meyer, showed that sugarcane growing on grey light-textured soils low in organic matter content would be most prone to S deficiency.

FOLIAR DIAGNOSIS

Leaf analysis has been used to great advantage in assessing the nutrient status of sugar cane, and it compares favourably with soil analysis in correlating with fertilizer responses, providing a useful check on the uptake of fertilizers already applied. Results of investigations by Meyer of the Diagnosis and Recommendations Integrated System (DRIS), based on nutrient indices derived from ratios between nutrients rather than the conventional nutrient percentage in leaf, have indicated that this system can help to expedite corrective fertilizer treatment in young cane. In particular DRIS can be used effectively to detect imbalances of N sooner than can be done by using the threshold value (Meyer and Wood).

WHOLE CYCLE FERTILIZER ADVICE

In 1973 the FAS at the Experiment Station introduced the present system of whole cycle fertilizer advice (Wood). This provides growers with a fertilizer recommendation for cane covering a whole crop cycle, i.e. a plant crop and four succeeding ratoons. Each recommendation is based on the chemical analysis of a fully representative pre-plant soil sample taken after the previous crop has been ploughed out.

CONCLUSIONS

During the past 40 years significant advances have been made in sugarcane nutrition. Many results have accumulated from soil and leaf analysis and crop performance on individual fields, while knowledge of the industry’s soils has greatly increased. It is now
REFERENCES

Agronomy
LA NUTRITION DE LA CANNE À SUCRE ET L'UTILISATION DES ENGRAIS EN AFRIQUE DU SUD

R.A. Wood

South African Sugar Association Experiment Station
Mount Edgecombe, Afrique du Sud.

EXTRAIT

Depuis les quatre dernières décennies, des recherches abondantes ont été entreprises en Afrique du Sud sur les besoins en engrais de la canne à sucre, qui ont entraîné de changements importants dans l'évolution de l'utilisation des engrais. Les taux de N, P, et K utilisés sont mis à jour suivant les résultats des essais au champ. Les corrélations établies entre les données du sol, les analyses foliaires et la réponse au champ aux différents doses d'éléments nutritifs sont discutées. Les recommandations en engrais sui-
vat les analyses du sol et des feuilles ont fourni des guides valables pour déterminer les besoins en fertilisant de la canne à sucre. Plusieurs facteurs édaphiques affectant la disponibilité en éléments nutritifs des plantes exigent une mise à jour périodique des recommendations courantes.

LA NUTRITICION Y FERTILIZACION DE LA CAÑA DE AZUCAR EN AFRICA DEL SUR

R. A. Wood

Estación Experimental de la Asociación de Azucareros del Africa del Sur, Mount Edgecombe, Africa del Sur.

RESUMEN

Durante los últimos 40 años se han investigado ampliamente los requisitos nutritivos de la caña de azúcar en África del Sur, de tal forma que han habido cambios significativos en el uso y formulación de fertilizantes. Se discuten en este trabajo los valores N, P y K con relación de la producción de caña en experimentos de campo, así como las correlaciones entre análisis de suelos, foliares y respuesta de la cosecha a los distintos nutrientes. Los análisis de suelos y foliares han servido para determinar los requisitos de nutrientes en la caña de azúcar. Ciertas condiciones de suelos, que afectan la disponibilidad de nutrientes, hacen necesaria la revisión periódica de las recomendaciones.