# PLANT NUTRITION AND FERTILIZER USAGE WITH SPECIFIC REFERENCE TO SUGARCANE

(Met opsomming in Afrikaans)

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**Abstract**

The amounts of N, P and K fertilizers used in the South African sugar industry increased between 1951 and 1966 due to increasing areas under sugarcane crops, and to large increases in the amounts of N and K fertilizers applied per acre. During a three-year period of restricted production from 1961 to 1963, the amounts of fertilizers used were greatly reduced. The approximate mean ratio of elements used in normal times in the industry is 4.5N : 1P : 4K.

Fertilizer recommendations for nitrogen are based on expected yields, but phosphorus and potassium carriers are recommended on the basis of soil and/or leaf analysis.

**Introduction**

Sugarcane has been grown in some areas of Natal for over 100 years without any apparent deterioration in the production potential. In fact, productivity has increased considerably over the past 30 years as farmers have learned to apply fertilizers correctly. At present it can safely be said that yields are limited to a far greater extent by inadequate water than by any other factor such as nutrition, cultural practice or disease.

The cane belt today extends from Umzimkulu in the south to Malelane in the north, a distance of more than 400 miles. The land under cane is fairly continuous along the coastal belt as far north as Mtubatuba, but beyond the Umfolozi river the cultivated areas are widely separated, being located in irrigable centres such as Pongola, Kaalrug, Malelane and Komatipoort. The topography varies from very steep hillsides in the south to flat alluvial areas in the north.

Approximately 38 soil series have been identified in the cane belt and these vary from the wind blown Fernwood sand to much heavier soils such as the Milkwood and Rydalvale clays. The wide textural and chemical differences between these extremes are shown in Table 1. There are large continuous areas of single soil series, particularly those derived from Table Mountain sandstone in the higher altitude areas, but there tends to be a fragmentary distribution of many of the soils nearer the coast, and sands and clays often occur within the boundaries of single fields.

*TABLE* 1. *Some physical and chemical properties of the surface strata of two Natal soils*

| Series | Fernwood | Rydalvale |
|---|---|---|
| Depth | 0–8″ | 0–7″ |
| Mechanical analyisis | | |
| % Clay | 5.7 | 52.5 |
| % Silt | 1.7 | 21.0 |
| % Fine sand | 29.5 | 16.3 |
| % Coarse sand | 63.1 | 10.2 |
| Soil moisture, in./ft | | |
| Field capacity | 1.7 | 5.1 |
| Wilting point | 0.7 | 3.8 |
| Available | 1.0 | 1.3 |
| Total exchange capacity; m.e. % | 3.6 | 47.6 |
| pH | 5.5 | 5.7 |

Of the 875,000 acres of land under sugarcane in the Republic of South Africa, only 15 per cent is irrigated. Approximately 53,000 acres of irrigated land lie north of Mtubatuba, where dryland sugarcane production is not possible and total irrigation is therefore practised. In the south, supplementary irrigation has been practised on some of the large estates for more than 30 years, and about 50,000 acres south of Mtubatuba are now partially irrigated. Dryland production in these areas is normally feasible, but rainfall is the major factor limiting average production to less than 20 tons of cane per acre per annum. The mean annual rainfall at Mount Edgecombe is approximately 38 inches, concentrated mainly in the critical summer months, but the distribution is so erratic that droughts and floods have accurred in almost every month of the year over the past 50 years.

## Amounts of Fertilizer Nutrients Used

### Total fertilizer usage

Over the past 16 years there have been enormous increases in the amounts of nitrogenous and potassic fertilizers used in the sugar industry, but over the same period there has been only a relatively small increase in the amount of phosphatic fertilizer used per annum. This is evident from the data shown in Table 2, where it can be seen that between 1951 and 1966 there was more than a nine-fold increase in the amount of nitrogen in fertilizers used, and more than a twenty-fold increase in the amount of potassium, whereas the amount of phosphorus in phosphatic fertilizers used was barely doubled.

The amounts of N and K in fertilizers used annually showed a progressive increase from 1951 to 1959 due mainly to increasing farmer appreciation of the value of correct fertilisation. Restricted sugarcane production from 1960 to 1962, however, resulted in an immediate decrease in the amounts of all fertilizers used during this 3-year period. Production in 1960 was limited to 77 per cent of the maximum potential, known as the "farm mean peak" (FMP). In 1961 production was limited to 80 per cent of FMP. At the start of the 1962 season production was again based on 80 per cent of FMP, but this was raised in the middle of the season to 90 per cent, and by the end of the season restrictions had been entirely removed.

Following upon the period of restriction the Republic was able to exploit overseas markets when the world price of sugar was extremely high. This called for maximum production as soon as possible, and record quantities of N, P and K fertilizers were used during the ensuing four years, reaching a peak in 1964-65 and declining slightly in 1966. Data for the amounts of nutrients in fertilizers used during 1967 in the canebelt are not yet available, but indications are that these have fallen still further below the record amounts, due no doubt to the low world sugar price which has prevailed in more recent years.

The relatively large amounts of P fertilizers used in the 4-year period from 1963 to 1966 inclusive were mainly a reflection of the large acreages being freshly plan-

*TABLE 2. Amounts of fertilizer elements used in the South African sugar industry from 1951 to 1966*

| Year | Nutrient elements used | | | | | | Ratio N:P:K |
|---|---|---|---|---|---|---|---|
| | N | P | K | N | P | K | |
| | *t | t | t | lb cane | lb cane | lb cane | |
| 1951 | 2,135 | 2,852 | 699 | 0.89 | 1.19 | 0.29 | 0.7:1:0.2 |
| 1952** | — | — | — | — | — | — | — |
| 1953 | 3,327 | 2,502 | 1,421 | 1.07 | 0.80 | 0.46 | 1.3:1:0.6 |
| 1954 | 4,516 | 2,624 | 2,335 | 1.22 | 0.71 | 0.63 | 1.7:1:0.9 |
| 1955 | 5,856 | 2,265 | 3,788 | 1.46 | 0.56 | 0.95 | 2.6:1:1.7 |
| 1956 | 7,397 | 1,969 | 4,802 | 1.96 | 0.52 | 1.28 | 3.8:1:2.5 |
| 1957 | 6,875 | 1,492 | 6,133 | 1.60 | 0.35 | 1.43 | 4.6:1:4.1 |
| 1958 | 10,164 | 2,342 | 9,873 | 1.98 | 0.46 | 1.93 | 4.3:1:4.2 |
| 1959 | 11,324 | 2,613 | 10,558 | 2.48 | 0.57 | 2.32 | 4.4:1:4.1 |
| 1960 | 7,344 | 1,908 | 6,482 | 1.70 | 0.44 | 1.50 | 3.9:1:3.4 |
| 1961 | 4,706 | 1,270 | 4,972 | 1.00 | 0.27 | 1.06 | 3.7:1:3.9 |
| 1962 | 6,577 | 1,808 | 5,969 | 1.22 | 0.34 | 1.11 | 3.6:1:3.3 |
| 1963 | 17,085 | 4,318 | 16,054 | 3.12 | 0.79 | 2.93 | 3.9:1:3.7 |
| 1964 | 19,533 | 5,690 | 20,288 | 3.32 | 0.97 | 3.45 | 3.4:1:3.6 |
| 1965 | 19,522 | 6,820 | 17,854 | 4.21 | 1.47 | 3.85 | 2.9:1:2.6 |
| 1966 | 18,974 | 3,974 | 15,779 | 2.44 | 0.51 | 2.03 | 4.8:1:4.0 |

* Tons of 2,000 lb.
** Data for 1952 not available.

ted as the industry expanded rapidly. Many of the new areas consisted of virgin veld where the available soil P contents were extremely low. The general procedure in the cane belt is to band heavy applications of superphosphate in the furrow at planting, and to supplement this with relatively light top-dressings of P fertilizers only on later ratoon crops.

**Amounts used per acre and per ton of cane produced**

The interpretation of data for total amounts of fertilizer nutrients used is limited due to fluctuations in the area under cane. The total area under cane in each year from 1951 to 1966 is shown in Table 3, and it can be seen that there was almost a 100 per cent increase over this 16-year period. The mean amounts of N, P and K in fertilizers used annually per acre have been calculated and are shown in Fig 1. The fairly consistent increase in N and K fertilizers used per acre from 1951 to 1959 is again apparent, followed by the radical decrease during the period of restricted production. Maximum N and K fertilisation per acre, however, occurred during 1963 and 1964, the decline becoming clearly apparent in 1965.

The mean amount of P in fertilizers used per acre declined gradually over the 10-year period from 1951 to 1961. This may have been due to increasing farmer appreciation of the necessity for balanced fertilisation, but was also no doubt a result of longer ratooning as more adequate amounts of N and K fertilizers were being used. The high amounts used per acre under cane in 1963, 1964 and 1965 again reflect the large planting programmes and expansion taking place at the time. The 1966 figure shows a rapid decline towards the normal level which now seems likely to be maintained. It is of interest to note that, whilst restricted production led to an immediate, rapid decrease in the use of expensive N and K fertilizer materials, the reduction in the mean amount of P used per acre over the same period was relatively slight.

As has been mentioned, rainfall is the single most severely limiting factor in sugarcane production in Natal. Evidence of this is shown in Table 3, where it can be seen that the mean yield in 1965, following a severe summer drought, was only 12.9 tons of cane per acre, compared with 19.0 and 18.6 tons per acre in the preceding and succeeding years respectively. The economic

*TABLE 3. Crop production and mean yields in the South African sugar industry from 1951 to 1966*

| Year | Sugarcane harvested | Total area under sugarcane | Mean yield |
|---|---|---|---|
| | *t | a | **t |
| 1951 | 4,805,249 | 422,422 | 11.0 |
| 1952 | 5,722,583 | 459,173 | 13.5 |
| 1953 | 6,221,531 | 526,959 | 13.5 |
| 1954 | 7,374,241 | 533,564 | 14.0 |
| 1955 | 8,005,990 | 562,427 | 15.0 |
| 1956 | 7,533,371 | 572,746 | 13.4 |
| 1957 | 8,594,618 | 591,872 | 15.0 |
| 1958 | 10,257,876 | 616,013 | 17.3 |
| 1959 | 9,123,396 | 633,805 | 14.8 |
| 1960 | 8,649,617 | 637,230 | 13.6 |
| 1961 | 9,384,090 | 636,618 | 14.7 |
| 1962 | 10,748,908 | 608,915 | 16.8 |
| 1963 | 10,956,448 | 616,916 | 18.0 |
| 1964 | 11,752,031 | 719,689 | 19.0 |
| 1965 | 9,266,324 | 810,687 | 12.9 |
| 1966 | 15,545,625 | 835,938 | 18.6 |

* Tons of 2,000 lb.
** Yields refer to sugarcane harvested per acre under cane during the previous year.

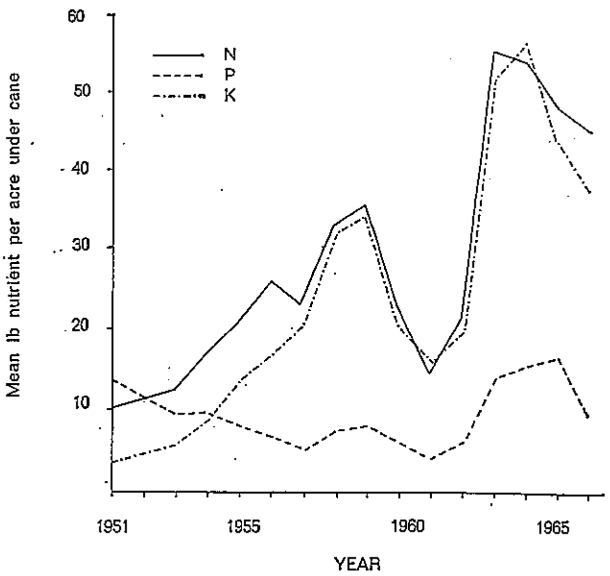


Fig. 1 — Mean amounts of N, P and K fertilizers used annually per acre.

appreciation of fertilizer usage can therefore best be made in terms of the amounts of nutrients used per ton of cane harvested. These data are shown for N, P and K separately in Table 2, and they indicate that normal is approximately 2.5 lb N, 0.5 lb P and 2.0 lb K per ton of cane harvested. In drought years these figures naturally increase, and in periods of expansion the amount of P particularly may increase considerably.

**Ratio N : P : K**

If the amount of P used in the industry annually is taken as a reference, the relative amounts of N and K used can be calculated. These ratios are shown in the final column of Table 2, and they illustrate again the marked increase in attention given to N and K fertilizers over the past 16 years. The progressively greater emphasis on N fertilisation followed upon the opening of the South African Sugar Association Fertilizer Advisory Service (FAS) in 1953. It was necessary to overcome farmer prejudice against using large amounts of N fertilizer per acre since it was a widely held opinion that heavy nitrogen fertilisation in drought years was not only uneconomic, but could actually suppress cane yields. From 1955 onwards, several of the large estates employed their own agronomists and established their own field laboratories. This also contributed materially to increased emphasis on N fertilisation.

The necessity for K fertilisation in many areas was first indicated by du Toit (1951). The general contention had been that sugar belt soils contained adequate amounts of naturally available K, but potassium deficiency symptoms began to appear in many fields. Emphasis on K fertilizer applications, where deficiencies were indicated by either soil or leaf analyses, developed rapidly due to the impact of both the FAS and the estate agronomists.

It would appear that the industry as a whole has tended to stabilise the relative amounts of nutrients used for sugarcane approximately in the ratio of 4.5N : 1P : 4K. When restrictions are imposed in sugarcane production, amounts of N and are likely to be reduced proportionally more than the amount of P, and during periods of expansion, the amount of P used is likely to increase proportionally more than the amounts of N and K.

**Economics of increased fertilisation**

Although yields over the past 16 years have been affected by factors other than increased fertilisation, it may be of interest to compare mean yields for three successive 5-year periods in relation to the mean amounts of ferilizer elements used per acre. The mean data are as follows:

| Period | lb/a N | lb/a P | lb/a K | Mean yield ton/a |
|---|---|---|---|---|
| A 1951-1956 (excl. 1952) | 17.2 | 9.6 | 9.6 | 13.5 |
| B 1957-1961 | 25.9 | 6.2 | 24.7 | 15.1 |
| C 1962-1966 | 45.0 | 12.4 | 42.0 | 17.2 |

The mean yield increases more than warranted the additional fertilizer costs for successive periods. In fact, the net value of a mean yield increase of approximately 0.3 tons cane per acre would have covered the cost of additional fertilizer (B-A), and the net value of 1.0 ton of cane per acre would have covered the cost of the additional fertilizer (C-B). It seems likely, therefore, that the increased fertilisation over the past 16 years has been economically warranted.

## Nutrient Carriers

In a recent review du Toit (1967) discussed the types of nitrogen fertilizers used in the South African sugar industry since 1957. The paper also included a review of experimental results from overseas cane-growing countries, and the general conclusion was that the cost per unit of nitrogen has been the principal determining factor in choosing the form of nitrogen fertilizer to be used. Although conditions do occur where one form of N fertilizer appears to be significantly superior to another, these have not yet been sufficiently well defined for recommendations regarding N-carriers to be based on anything more than the cost per unit of nitrogen applied.

The sugarcane yields obtained in the few instances where aqua ammonia or anhydrous ammonia have been used in Natal have been reassuring, and providing that this nitrogen carrier can be applied cheaply, it is likely to become popular in the future. It is already being used extensively in the newly-developed sugarcane areas of the Eastern Transvaal.

Forms of phosphate fertilizers have been discussed recently by Wyatt (1968). His conclusions were that superphosphate was to be preferred under alkaline, neutral and mildly acid soil conditions, but that rock phosphate might be better than superphosphate under very acid conditions. Only water-soluble forms of phosphate could be recommended for top-dressing ratoon crops.

Since sugarcane is not sensitive to the chlorine in muriate of potash, there has never been any reason to consider the more expensive sulphate to supply the crop's K requirements.

## Predicting Fertilizer Requirements

The nitrogen requirements of sugarcane have been the subject of a vast amount of field experimentation throughout the cane-growing world. The results of some 2,000 experiments conducted between 1900 and 1955 were reviewed by Casey and Robinson (1953) and by Hodnett (1956). More recently, Wood (1968) has reviewed overseas work and the results of more than 80 South African experiments which included amounts of nitrogen as treatments. The conclusion reached was that the response to nitrogen varied from season to season due mainly to variations in the amounts and distribution of rainfall. It was also found that responses to applied nitrogen were greater in ratoon crops than in plant crops.

It is interesting to note that the general recommendations were remarkably consistent from country to country, as can be seen in the following list:

| Country | lb N/a recommended |
|---|---|
| South Africa | 100 |
| Caribbean area | 94 |
| Queensland | 95 |
| Mauritius | 90 |
| Puerto Rico | 120 |
| Hawaii | 200 |
| Brazil | 120 |
| Egypt | 100 |
| Indonesia | 130 |
| Philippines | 100 |

It should be noted that in Hawaii, the crops are generally more than 24 months old and yield more than 100 tons of cane per acre. In the other nine countries mentioned, the range of recommendations is from 90 to 130 lb N per acre, and it is doubtful whether any recommendation is more accurate than approximately 40 lb N per acre.

It has been shown that the applied nitrogen requirements for plant cane is greater on some soils than on others (du Toit, 1957). Both this phenomenon, and the greater response of ratoons compared with plant cane to applied N, have been associated by Wood (1964) with the different rates of N mineralisation in the different soil series. The data for 13 soil series are reproduced in Table 4.

*TABLE 4. Relative capacities of sugar belt soils to mineralise soil nitrogen (two week inoculation period) after wood (1964)*

| Soil group and series | lb/N mineralised/a |
|---|---|
| T.M.S.—Cartref | 39 |
| Recent sand (grey)—Fernwood | 42 |
| Beaufort sand—Confluence | 54 |
| Middle Ecca—Windermere | 64 |
| Dwyka—Williamson | 68 |
| Lower Ecca—Milkwood | 74 |
| T.M.S.—Inanda | 75 |
| Recent sand (red)—Lytton | 84 |
| Granite—Mayo | 88 |
| Schist—Logoza | 88 |
| Dolerite (red)—Shortlands | 102 |
| Dolerite (black)—Rydalvale | 110 |
| Alluvium | 128 |

The nitrogen status of a sugarcane crop can be inferred from foliar analyses, providing that samples are taken from a vigorously growing crop in summer (Halias, 1963). However, the crop responds best to early applications of nitrogen fertilizer, and the leaf analyses are therefore only useful for checking on the adequacy of the nitrogen fertilisation, and not for estimating the future requirements of the crop.

Because neither soil nor foliar analyses can be used to predict future sugarcane crop requirements with any degree of accuracy, the procedure used for recommending nitrogen fertilisation in the sugar industry is based on the estimated yield to be obtained from the field to be treated. The summarised recommendations are:

Plant cane - 2.5 lb N/ton cane expected on Cartref, Waldene and Williamson series soils.
1.5 lb N/ton cane expected on all other soils.

Ratoon cane - 2.5 lb N/ton cane expected on all soils.

### Phosphorus

It was shown by du Toit (1957) that responses to phosphatic fertilizers were spectacular on virgin soils, but on old sugarcane lands the responses tended to decline, presumably due to a progressive accummulation of applied P over the many years during which P fertilizers were used almost to the exclusion of any other. It has also been shown (unpl. data) that the response in first ratoon crops was greater to furrow-applied phosphate than to topdressed phosphate. The tendency is therefore to apply sufficient P fertilizer in the furrow at planting to meet the requirements of the plant crop and at least one ratoon.

The P fertilizer requirements of the crop may be predicted on the basis of either soil or leaf analyses, and the procedures for recommending are shown in Table 5.

### Potassium

The K requirements of a sugarcane crop may be estimated either from soil or leaf analyses. The method of recommendation in the South African sugar industry is shown in Table 6.

### General

In past years when the costs of mixtures exceeded the costs of equivalent straight fertilizers by a considerable amount, many farmers and estates preferred to mix their own fertilizers. The industry's Fertilizer Advisory Service, however, has always offered advice in terms of both straight fertilizers and the most suitable mixture, even if the latter had to be reinforced with extra N or K carriers. The trend has been towards the use of mixtures in preference to straight fertilizers. On some

*TABLE 5. Methods for recommending phosphate fertilizer in the South African sugar industry*

| Plant cane | | Ratoons | | All crops | |
|---|---|---|---|---|---|
| Soil P | Supers recommended | Soil P | Supers recommended | Leaf P | Supers recommended |
| ppm | lb/a | ppm | lb/a | % | lb/a |
| 33 | Nil | >11 | Nil | 0.20 | Nil |
| 26 | 300 | 9.5 | 200 | 0.17–0.19 | 200 |
| 22 | 400 | 6 | 250 | 0.17 | 300 |
| 17 | 500 | 4 | 300 | | |
| 13 | 600 | | | | |
| 9 | 700 | | | | |
| 4 | 800 | | | | |

*TABLE 6. Methods for recommending potassic fertilizer in the South African sugar industry*

| Soil analysis | | Leaf analysis | |
|---|---|---|---|
| Soil K | Muriate of Potash recom. | Leaf K | Muriate of Potash recom. |
| ppm | lb/a | % | lb/a |
| 125 | Nil | 1.10 | Nil |
| 100 | 200 | 1.00—1.10 | 200 |
| 75 | 300 | 0.90—1.00 | 300 |
| 50 | 400 | 0.80—0.90 | 400 |
| 25 | 500 | | |

of the large estates, where more than 10 years of scientific fertilisation has tended to balance the soil nutrient status, the programmes are being limited for convenience to a small choice of mixtures.

## Future Developments

The aspects of sugarcane nutrition which probably deserve most attention in the immediate future are those of a practical nature. There is undoubtedly more to be gained, in terms of return on investment, from correct timing, placement and distribution of fertilizer than from any refinement in the recommendation procedures at this stage. Research projects will nevertheless continue on such fundamental subjects as nitrogen release from the soil and the role of minor elements in the sugar industry.

Within the industry there is constituted an informal group known as the South African Sugar Industry Agronomists' Association, whose efforts are currently directed towards the collation and reviewing of the considerable amount of experimental data which has accumulated on the estates and at the Experiment Station. Reviews by du Toit (1967), Wood (1968) and Wyatt (1968) are the products of this effort so far, and reviews on a number of additional subjects are in preparation.


Opsomming

*PLANTVOEDING EN MISSTOFVERBRUIK MET SPESIFIEKE VERWYSING NA SUIKERRIETPRODUKTE*

*Vermeerdering van opbrengste oor die hele suikerindustrie gedurende die afgelope 16 jaar was gedeeltelik te wyte aan vermeerderde en meer gebalanseerde toediening van kunsmis. Nie alleenlik het die oppervlakte onder suikerriet verdubbel sedert 1951 nie, maar die stikstoftoediening het ook negevoudig en die kaliumtoediening twintigvoudig toegeneem. Kunsmisverbruik het voortdurend toegeneem behalwe vir 'n tydperk van twee jaar vanaf 1960 tot 1962 toe beperkings op suikerrietverbouing 'n groot tydelike vermindering in kunsmisverbruik veroorsaak het. Die gemiddelde opbrengstoename in die industrie het die koste van die vermeerderde kunsmisverbruik meer as regverdig alhoewel ander faktore onvermydelik bygedra het tot die toename in opbrengs. Die normale verhouding van voedingstowwe gebruik in die industrie as geheel skyn te wees 4.5N: 1P: 4K. Die S.A. Suikervereniging se Navorsingstasie te Mount Edgecombe verskaf 'n kunsmisaanbevelingsdiens aan alle suikerrietprodusente in die Republiek. Stikstofaanbevelings word gebaseer op die verwagte opbrengs en is gemiddeld 100 lb. N per acre. Die belangrikste faktor by die keuse van 'n stikstofdraer is die koste per stikstofeenheid toegedien op die land. Fosfaat- en kaliumaanbevelings word gebaseer op grond en/of blaarontledings waarvoor redelik betroubare limietwaardes vasgestel is. Die huidige tendens is om meer mengsels en minder ongemengde kunsmis te gebruik. Daar word gevoel dat op die oomblik nader gekom kan word aan die maksimum ekonomiese opbrengs deur verbetering van die tyd van toediening, plasing en verspreiding van die kunsmis op die land as deur verfyning van die metodes van kunsmisaanbevelings.*


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