

A NUTRIENT SURVEY OF CANE ON T.M.S. SOILS IN NATAL

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Introduction

Early in 1966 it was decided that a controlled survey of the nutrient status of sugarcane as determined by analysis of leaf samples would be of benefit to cane-growers in South Africa. By locating in this manner which areas are deficient in certain nutrients, and particularly trace elements, it is possible to give growers, regional representatives, and laboratory analysts advance warning of nutrient difficulties. This in turn makes it possible for corrective measures to be applied at an early date.

Sampling Technique

The availability of nutrient in the soil is only one of many factors which can influence the concentration of minerals in cane-leaves. The more important of these other factors are the variety used, its state of maturity, whether it is a plant or ratoon crop, the season of the year, and the preparation of the leaf sample prior to drying. In order to standardize sampling procedure as much as possible, it was decided that the same person should take all samples; that only one variety, N:Co. 376, would be sampled; and then only from ratoon crops. The age of the crop would be standardized between narrow limits by restricting sampling to cane cut between 6 and 7 months previously. Sampling was to be completed in the shortest possible time, and would be confined to the optimum period, January/February.

Areas and Soils

Restrictions imposed by the sampling technique considerably restricted the area that could be sampled. It was decided therefore to sample only those fields in which the soil was derived from Table Mountain sandstone (T.M.S.). This was done for two reasons. In the first place this is the largest soil group in the sugar industry, comprising nearly 20% of the total area under cane, and secondly, one of its series was known to suffer from our most widely distributed trace element deficiency, namely that of zinc. In Natal, the T.M.S. group of soils can be divided into two main series, Cartref and Inanda, and two minor series, Solferino and Trevanian. The Cartref series has been derived directly from the sandstone itself (Beater 1957). Maud (1965) suggests that the Inanda series has been formed by the weathering of a relatively thin lateritic layer, which is now of the order of 10 ft. in thickness, and which caps the T.M.S. in the plateau areas.

The T.M.S. formation is about 2,000 ft. thick in Natal, and was laid down about 500 million years ago. Since quartz is its main ingredient, and its development was mainly from fast-moving sediments, it is not rich in plant minerals. The acid lateritic soil which is characteristic of the Inanda series is high in organic matter, and is frequently referred to as a "mist-belt" T.M.S. soil. It is well-leached, and contains high concentrations of iron and aluminium oxides and hydroxides. It was on this soil that zinc deficiency was first identified on sugarcane in South Africa (du Toit 1962).

Number of Samples

Two hundred and sixty farms out of all those for which soil maps were available at the time of this survey were shown to be partly or wholly on T.M.S. soils. It was appreciated that while some farms might yield up to three suitable samples, others might not yield any, hence an average of one sample per farm visited was made the objective. Sampling began on 17th January, 1966, and was completed six weeks later on 3rd March. At this stage 196 samples had been collected. A few of these had to be rejected later, either because they were located on an incorrect soil or because they were in the wrong cane age-group. Rain prevented sampling on several days. The survey coincided with the seasonal close-down of the mills, and many farm-owners were away on vacation when their farms were visited. The person left in charge seldom had the necessary field particulars, and in these circumstances no sample was taken.

Practical Aspects

When a selected farm was visited, the owner or manager would be asked if any of his fields on T.M.S. soils carried the variety N:Co. 376 which had been cut during July and August, 1965. When there was such a field the grower invariably pinpointed the location. The field number and soil type were then checked on maps carried for the purpose, and the identity of the cane variety confirmed. Fifty "third leaves" (corresponding well with "top visible dewlap leaves") were then collected. The tops and bottoms of the leaves were cut off using a vee-shaped wooden channel as a template. The midribs were immediately stripped out and discarded, leaving only the 12-inch central laminar portion of the leaves. These were tied in a bundle, carefully labelled, and placed in a specially constructed dust-proof box. A soil

TABLE I
Nutrient levels in 3rd leaf laminar samples

	Nitrogen N%	Phosphorus P%	Potassium K%	Magnesium Mg%	Calcium Ca%	Sodium Na%	Zinc Zn ppm	Copper Cu ppm	Manganese Mn ppm
Mean of 68 samples from mist-belt fields . .	2.26	0.27	1.33	0.31	0.40	0.023	13.2	5.6	55
Mean of 120 samples from ordinary T.M.S. fields	2.14	0.28	1.38	0.25	0.37	0.042*	16.5	5.7	69
Overall mean of 188 fields	2.18	0.28	1.36	0.28	0.38	0.035*	15.3	5.6	64
Range over all fields sampled	1.57 to 2.84	0.18 to 0.41	0.70 to 1.95	0.12 to 0.47	0.26 to 0.71	0.009 to 0.218	6.2 to 29.4	2.8 to 10.6	22 to 176
Suggested minimum accepted nutrient concentration	1.70	0.20	1.10	0.08	0.12	—	12.0†	3.0	15

*Inflated values. See text.

†Evans (1959) suggests adequacy may even be below 10 ppm but later (1965) he quoted 15 ppm as the accepted adequacy level for zinc.

TABLE II
Number of samples in deficiency range

	N	P	K	Mg	Ca	Zn	Cu	Mn
Mist-belt fields	Nil	Nil	14	Nil	Nil	28	2	Nil
Ordinary T.M.S. fields . .	4	1	17	Nil	Nil	4	2	Nil

sample was then taken for associated studies on soluble silica and aluminium toxicity (Bishop 1967).

Up to 14 farms per day were visited and, whenever possible, the day's collection was dried overnight at 110°C, using a forced draught thermostatic oven at the Experiment Station. The leaves were not washed prior to drying and grinding. The grinding was carried out in a steel mill, employing a fine mesh steel sieve. Although this would obviously invalidate any attempts at iron determinations, no contamination by other elements occurs.

Analytical Methods

The analytical methods employed were as follows: Nitrogen was determined by the macro-Kjeldahl technique. Phosphorus was determined by a colorimetric procedure employing molybdic acid and stannous chloride. Potassium, calcium and sodium were all analysed on an "Eel" flame-photometer. The titan yellow method was used for magnesium, while zinc and copper were determined using dithizone as the colour reagent. The manganese figures were also obtained colorimetrically, by oxidising the manganese with potassium periodate.

Results

The main analytical results are given in Tables I and II. Zinc levels were deficient in leaves obtained

from cane grown on 28 mist-belt fields and four ordinary T.M.S. fields. There is still some doubt about classification of soil-types in these four fields, and it may well be that zinc deficiency is confined to the mist-belt soils only. Such deficiency symptoms as chlorosis, smallness of the leaves, patchy growth and stunting were prevalent in a number of the fields later found to be low in leaf zinc. Low zinc levels occurred in leaves taken from fields at Paddock, east of Mid-Illovo, Upper Tongaat, Doringkop, Entumeni and Eshowe.

Zinc uptake by plants has been shown to increase as soil temperatures rise. (Ellis, *et al*, 1964); and Bauer and Lindsay, 1965). This means that when sampling is carried out following a warm sunny season an enhanced overall level of zinc will be found in the leaves. Records kept at Mount Edgecombe, which is roughly in the centre of the sampled area, show that during the three months preceding the survey, the mean soil temperature at a depth of 4 ft. was 3°F below the past 31-year average. It is likely therefore that the concentration of zinc found in cane leaves during this survey is a little lower than it would be during some other years. Despite this, the extent of the deficiency indicates that growers in the affected areas should acquaint themselves with the symptoms of zinc deficiency on both sugarcane and maize.

For cane, the corrective treatment for soils known to be deficient in zinc is the application in the furrow

of 50 lb. per acre of commercial zinc fertilizing material, containing 22% Zn. Since zinc does not normally move in the soil, it should be placed where the greatest concentration of roots is expected to occur. According to Ellis, *et al* (1964), the presence of phosphatic fertilizer in contact with the zinc fertilizing material sometimes impairs the uptake of zinc by plants. This obviously creates a problem for the grower whose soil needs the simultaneous application of both fertilizers.

Copper deficiency was found in four instances, but three of these were right on the threshold value and must be considered as marginal. No cases of manganese deficiency were found.

Although sodium is not considered to be essential for optimum growth of cane, this element was determined on all samples taken. A considerably higher content of leaf-sodium was immediately detected in 14 samples taken from farms in a small area north-east of Gingindlovu. The sodium content for these samples averaged 0.171%, which was roughly seven times the level found in the other 174 samples (0.025%). The proximity of the sea was first thought to be responsible, yet other farms which were the same distance from the sea had far lower levels of leaf-sodium. Poor soil aeration may be a factor connected with this phenomenon, but there was no evidence of this in the crops involved. Beater (1967) has pointed out that the samples taken in Zululand were probably from the Solferino series. This is a hydromorphic soil derived from T.M.S., the lower horizons of which are found to contain an appreciable amount of exchangeable sodium.

Good responses are normally expected when nitrogenous fertilizers are applied as top-dressings to cane grown on T.M.S. soils. It was surprising therefore that in only four cases was the level of leaf nitrogen low enough to be classified as deficient. The four fields involved were all on ordinary T.M.S. soil. A further wholly unexpected result was that only one leaf sample (T.M.S. ordinary) out of 188 revealed a phosphorus deficiency. The level of available phosphorus in these soils is frequently very low, and substantial increases in yield often follow the application of phosphatic fertilizers.

In contrast with the result for N and P, potassium deficiency was found in samples representing 16.5% of the area examined. Fourteen mist-belt fields, and 17 ordinary T.M.S. fields were found to be low in potash. This confirms the work of du Toit (1951), whose cane growth-rate experiments on T.M.S. soils showed excellent responses to applied potassic fertilizer. The critical level for K in third leaf laminae in these studies is 1.1%. This is lower than that accepted in some cane-growing countries overseas, and Evans (1965) quotes a figure of 1.25% K for British Guiana. If a compromise level of 1.2% K were to be adopted as the criterion, then the number of fields considered to be low in potash would have been doubled. No deficiencies of calcium or magnesium were indicated by the leaf analysis.

Discussion and Conclusion

From Table I it can be seen that cane fields in both the mist-belt and on ordinary T.M.S. soils are

reasonably similar in their ability to provide the crop with nitrogen, phosphorus, potassium and copper. Leaves from cane grown on mist-belt soils were appreciably higher in magnesium and calcium than those from cane grown on T.M.S. (ord.). Leaves from cane grown on ordinary T.M.S. soils, however, contained more zinc and manganese. The level of organic matter in mist-belt soils is often ten times that found in the Cartref series soils (Bishop, 1967). It has been demonstrated by Smith *et al* (1962) that the presence of organic material in the soil tends to fix zinc and this may account in part for the reduced availability of this element in mist-belt soils.

In due course analyses to determine boron and molybdenum will be carried out on the samples collected during this survey. It is not thought that deficiencies of sulphur or chlorine are likely to occur in the cane-belt, as sulphate of ammonia, superphosphate, and potassium chloride are widely used as fertilizers. Iron deficiency is also virtually ruled out on the acid, iron-rich soils in the T.M.S. group.

Summary

Analyses of 188 carefully-gathered leaf samples from cane grown on Table Mountain sandstone soils in Natal and Zululand indicate fairly widespread zinc deficiency. This deficiency is confined almost exclusively to the mist-belt T.M.S., belonging to the Inanda series. Four samples appeared to be low in copper and are regarded as marginally deficient in this element. No cases of deficiency or toxicity in manganese were found. Determination of boron and molybdenum levels are to be carried out at a later date. The availability of the major elements was also determined on the same samples and the only important deficiency was potassium. It seems likely that a shortage of this element affects at least one-sixth of the sugarcane growing on T.M.S. soils.

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Discussion

Mr. Ric-Hansen: Mr. Alexander took leaf samples when the cane was six months old. Possibly the farms had had different top dressings and these would affect his leaf analysis.

Mr. Alexander: Full particulars were taken of each field that was sampled. About 95% had been top dressed but it did not always follow that those with a deficiency had not been top dressed.

Mr. Gilfillan: No deficiencies of nitrogen or phosphorus were found in the leaf although in T.M.S. soils the greatest response is to these applications.

The whole survey was done by leaf analysis but would it not be more satisfactory to determine these trace elements by soil analysis?

Mr. Alexander: The absence of deficiencies in nitrogen and phosphorus did surprise me. It has been suggested that the deficiencies were there but were not disclosed by the leaf sampling.

In most cases the crops examined appeared to be in excellent condition, but deficiencies are not always apparent. Zinc deficiency was apparent in a number of cases and this was confirmed by leaf analysis.

At present we do not have a satisfactory method of determining trace elements by soil analysis but we are working on this.

Mr. du Toit: There are three reasons why not many deficiencies of nitrogen have been found.

The first is the suggested minimum that has been set, in this case 1.70%.

Secondly, 95% of the fields had been top dressed and sampling was done shortly thereafter and consequently nitrogen, as reflected by leaf analysis, would be satisfactory.

Thirdly, there has been a very great increase in the amount of nitrogen used in the industry, in fact filter cake analyses show double the amount of nitrogen, compared with a few years ago.

The phosphate position is not surprising either. Phosphate deficiency in the sugar growing areas is unusual, except in virgin soil.

The number of zinc deficiencies is surprising, and also the four instances of copper deficiency, but again this is in relation to the suggested minimum figures, which may be unrealistic.

It seems to have been established from an analytical and observational point of view that zinc deficiency is more common than we had thought.

In growth failure areas zinc deficiency may play a part but it is not the whole answer.

Dr. Matic: Professor Ahrens at Cape Town University has developed a number of methods for trace element analysis.

In view of the fact that differences appear in the top and bottom of the leaf it may, in the case of potassium for instance, make a big difference where the sample is taken on the leaf.

Mr. Alexander: A definite part of a specified leaf

has been decided on for sampling purposes which enables us to make comparisons with overseas results.

Mr. Rogers: Is boron deficiency measured?

Mr. Alexander: We are preserving samples so that in the near future they can be analysed for boron and molybdenum. We know the symptoms of boron deficiency but they have not been observed in this country. Boron is difficult to analyse and is present in very small quantities in cane leaves.

Mr. Bishop: Our Inanda series soil is highly leached and acidic and yet the average calcium value is 0.4% against a threshold value of 0.12%, and leaf magnesium is also high.

How often have you seen a leaf calcium figure that is below the threshold value and what proportion of your recommendations involving lime would be based on a leaf analysis?

Mr. Alexander: One certainly would have expected cases of calcium and magnesium deficiency or near deficiency.

In our recommendations to growers who send in leaf samples I have never yet recommended lime on the basis of a leaf analysis, although there have been a few cases where Dolomitic lime has been recommended in order to raise a low leaf-magnesium figure.

Dr. Cleasby (in the chair): On certain T.M.S. soils at Tongaat, where calcium has been well below threshold value, based on soil analysis, we have had liming trials without significant response.

Mr. du Toit: I have not seen a single instance in South Africa of a leaf symptom which has been proved to be due to calcium or magnesium deficiency.

Occasionally I thought I had seen symptoms of boron deficiency but in every case it was almost certainly Pokkah Boeng.

Mr. Brown: Why should our soil not be getting the benefit of calcium from the superphosphate supplied?

Mr. Alexander: Superphosphate will usually supply a crop's calcium requirements. Calcium and magnesium are removed by the cane and sent to the mill in larger amounts than is phosphorus, in many instances.

Dr. Cleasby: Are you satisfied that in T.M.S. soils you will always get a response to applications of potash where the leaf shows a deficiency? I ask this particularly in the light of an experiment at Tongaat on a T.M.S. soil which ran in two cycles for sixteen years and did not respond to potash in spite of soil and leaf analyses indicating a deficiency.

Mr. Alexander: In these soils we would expect a response to potassium where either leaf or soil analysis indicates a deficiency of this element. There have been occasional inexplicable instances such as the experiment which you mention.