FERTILITY TRENDS IN THE SOUTH AFRICAN SUGAR INDUSTRY

By J. H. MEYER, R. A. WOOD and R. L. HARDING

South African Sugar Association Experiment Station, Private Bag X02, Mount Edgecombe

Abstract

Since the nutrient survey of the South African sugar industry in 1970 little use has been made of analytical data for determining trends in soil fertility and plant nutrient uptake in the regional extension areas of the industry. This became possible in 1980 following computerisation of fertilizer recommendations by the Fertilizer Advisory Service (FAS) of the Experiment Station. Since then a data bank has stored information from approximately 100 000 soil and about 35 000 leaf samples that have been analysed for cane growers.

The data set for soils comprised information with regard to pH, the elements P, K, Ca, Mg, S, Zn and also percentage clay, P-fixation and Al toxicity. The leaf data set was concerned with the elements N, P, K, Ca, S and Zn. The retrieval system used for providing comparative changes in nutrient availability during the past eight years is described. Examples are given to show how the information may be used for extension purposes.

Introduction

Since the industry-wide nutrient survey conducted in 1970 (Meyer *et al*[4]), little quantitative information has been reported regarding changes in fertility status in various parts of the sugar industry. In 1980 soil and leaf analyses together with fertilizer recommendations were fully computerised. To date, analytical data from about 100 000 soil and 35 000 leaf samples have been stored in the data bank. The development of programmes for retrieving data proceeded in three stages as follows:

1. *Grower field history reports* which summarise soil and leaf analyses chronologically on a field by field basis.
2. *Nutrient survey programmes* which categorise the frequency distribution of each nutrient into various stages of sufficiency (ie very low, low, moderate, satisfactory, high and excessive). The classification variables also include five soil systems or bioclimatic regions, 15 extension areas including Swaziland and 15 soil parent materials. In the case of leaf samples additional variables included four sampling ages and month of sampling.
3. *Whole farm fertilizer recommendations* which are intended to reduce fertilizer recommendations for plant and ratoon cane to a minimum number of mixtures.

The main objective of this paper is to provide an update on comparative changes in nutrient availability in the sugar industry since the 1970 survey.

Materials and methods

Nature of the data set

An IBM 4331 mainframe computer was used to process soil and leaf analyses and the data were stored on mainframe disc files. The main soil data set comprised pH (H_2O), P, K, Ca and Mg values of about 100 000 soil samples which were analysed by the Fertilizer Advisory Service (FAS) between 1980 and 1988, together with information which identifies the extension area, soil system and soil parent material. Supplementary analyses for about 35 000 soil samples, mainly from the Natal midlands region, provided additional information on phosphorus desorption index (PDI), exchangeable aluminium index (EAI), Zn and S. Since 1985 the classification of soils into four categories (low, medium, high and very high) according to their potential to mineralize N from soil organic matter (Meyer *et al*[6]) has resulted in N ratings for about 45 000 samples. These have been included in the data bank.

The leaf data set was smaller than the soil set and comprised N, P, K, Ca, Mg, S and Zn analyses for about 35 000 leaf samples plus site details relating to month and age of sampling, cane variety, soil system, extension area and, where available, soil parent material.

Both data sets were each further divided into three periods (1980–82, 1983–85 and 1986–88) with a view to determining possible changes in nutrient status with time. For reasons of standardisation the computer was programmed with the same class intervals as those currently used in FAS tables for assessing crop nutrient requirement. The ranges used for categorising soils and leaves are shown in Table 1.

Description of classification variables

The four bioclimatic regions covered in this study included the coast lowlands, coast hinterland, midlands mistbelt and lowveld. The regions were further subdivided into the five soil systems as described by Macvicar[3] namely the Berea (16%), Umzinto coast lowlands (33%), Umzinto midlands (18%), Nottingham (15%) and Komatipoort (18%) systems.

The sugar industry is divided into 15 extension areas. These were selected as the second classification variable. Swaziland has been included as growers there have made use of FAS for many years and there is merit in comparing trends between Pongola, the Eastern Transvaal and Swaziland.

With regard to soil samples the area that made the greatest use of FAS were the North Coast (18%), Durban North Coast (11,5%) followed by Midlands North (9,4%) and Zululand South (9,3%). Leaf samples showed a different usage pattern, most samples coming from Durban North Coast (26%), followed by Swaziland (18%), North Coast (12%) and South Coast (9%).

Soil parent material was the third classification variable and provision was made for the 15 different parent materials that were originally used as a basis for surveying soils in the sugar industry (Beater[2]). Distribution of samples according to parent material showed that the six most important were TMS (ord) 25%, TMS (mistbelt) 15%, Dwyka tillite 10%, dolerite 9,4%, granite 9,0% and Middle Ecca sediments 8,4%.

Table 1

Limits of class intervals used in assessing the leaf and soil analytical data

No.	Interval	Leaf							Soil							
		N%	P%	K%	Ca%	Mg%	S%	Zn ppm	P%	K*	K**	K***	Ca ppm	Mg ppm	S ppm	Zn ppm
1	Very low	1,40	0,14	0,55	0,10	0,10	0,10	10	5	40	67	155	75	–	–	0,5
2	Low	1,41 –1,59	0,15 –0,16	0,56 –0,85	0,11 –0,15	0,11 –0,15	0,11 –0,15	10-12	6 –9	41 –67	68 –110	111 –155	75 –150	26	10	0,6 –1,0
3	Marginal	1,60 –1,79	0,17 –0,19	0,86 –1,05	0,16 –0,20	0,16 –0,20	0,16 –0,20	13-15	10 –14	68 –110	111 –150	156 –200	151 –350	27 –53	11 –20	1,1 –1,5
4	Satisfactory	1,80 –2,00	0,20 –0,24	1,06 –1,15	0,21 –0,30	0,21 –0,30	0,21 –0,25	16-20	15 –19	111 –155	151 –200	201 –245	351 –500	54 – 80	21 –30	1,6 –2,0
5	Adequate	2,01 –2,70	0,25 –0,30	1,16 –1,50	0,31 –0,40	0,31 –0,40	0,26 –0,30	21-25	20 –29	156 –200	201 –245	246 –400	501 –1 000	81 –132	31 –50	2,1 –3,0
6	High	2,70	0,30	1,50	0,40	0,40	0,30	25	30	200	245	400	1 000	132	50	3,0

* light to medium textured soils
** medium to heavy textured soils
*** heavy blocky clays (irrigated cane)

Analytical methods

The standard 1 N ammonium acetate method was used for extracting K, Ca and Mg from soils and subsequent determination was by atomic absorption. P was determined by the modified Truog procedure based on 0,02 N H_2SO_4, and pH by using a 1:2,5 soil:water ratio. EAI and PDI were determined according to Reeve and Sumner[8] and S turbidimetrically following extraction with 0,5 N ammonium acetate (Bardsley and Lancaster[1]). Zn was displaced with 0,01 M EDTA according to the method by Treirweiler and Lindsay.[10]

Prior to 1984, leaf samples were analysed by conventional wet digestion methods and subsequently by an integrated system, using near infra-red reflectance (Meyer[5]) and X-ray spectrometry (Wood *et al*[11]).

Results and Discussion

Bioclimatic regions

The mean values obtained for all nutrients that were analysed in the 35 000 leaf samples are summarised on a regional basis in Table 2, together with the percentage of samples rated as deficient. The main effects were as follows:

Table 2

Average nutrient content of leaf samples for the various bioclimatic regions

Natural Region	Soil system	N %	P %	K %	Ca %	Mg %	S %	Zn %
Coast Lowlands	Berea	1,84	0,21	1,21	0,27	0,22	0,17	18
	Umzinto	1,87	0,22	1,20	0,26	0,26	0,16	18
Coast hinterland	Umzinto midlands	1,95	0,22	1,42	0,29	0,25	0,19	17
Mistbelt	Nottingham	1,94	0,20	1,29	0,26	0,24	0,17	18
Lowveld	Komatipoort	2,03	0,25	1,32	0,34	0,27	0,15	19
Threshold values		1,60	0,17	1,05	0,15	0,10	0,12	13
Percentage samples deficient		13 (4)	12 (7)	28 (25)	4 (1)	1 (1)	18 (14)	8 (12)

( ) Percentage equivalent 1970 survey

1. Leaf analyses revealed relatively few deficiencies of Ca (4%), Mg (1%) and Zn (8%) and a somewhat higher incidence for N (13%), P (12%), and S (18%). A fairly high proportion of samples were deficient in K (28%).
2. Cane growing in the Berea and Umzinto coast lowlands systems showed the highest incidence of N deficiency (both 19%) with the Nottingham (8%) and Komatipoort (7%) systems showing the lowest incidence.
3. P deficiency was confined mainly to the Nottingham (16%) and Umzinto midlands (13%) soil systems. However, there was a relatively high proportion of samples with marginal to deficient P values, and these ranged from 27% in the Berea system to 40% in the Nottingham system. In all, 56% of leaf samples from the Nottingham system were marginal to deficient in P. (About the same proportion of soil samples were found to be from moderately to strongly P fixing).
4. The highest incidence of K deficiency occurred in cane growing in the irrigated areas of the Komatipoort system (41%) while the Nottingham system (14%) had the lowest incidence.
5. Samples deficient in Ca originated mainly from the Nottingham, Umzinto coast lowlands and Berea systems. A further 20% of samples from each of these systems was rated as marginal in Ca (0,16 to 0,20%). Although the incidence of Mg deficiency was very low, about 15% of all leaf samples were found to be marginal in this nutrient (0,11 to 0,15%).
6. S deficiency appeared to be confined mainly to the Umzinto coast lowlands (22%) and Komatipoort (24%) systems. The irrigated areas of the Eastern Transvaal and Swaziland accounted for a large proportion of these deficiencies with Zululand North and the lower South Coast making up the balance.
7. Zn deficiency showed an overall decline of 4% from the 12% of samples diagnosed as deficient in the 1970 survey. This may partly be due to the introduction of a wider range of zincated fertilizer mixtures during the past decade.

Soil samples

The mean values obtained for all soil nutrients from the various bioclimatic regions are summarised in Table 3 together with the threshold values denoting deficiency. The main findings were as follows:

(i) Approximately 51% of soils with less than 30% clay were marginal to deficient in K, while in the heavier textured soils, it was 56 and 59% in the rainfed and irrigated cane areas respectively. The number of soils rated as deficient in K was clearly far in excess of those showing leaf deficiencies. It was also substantially higher than the 40% identified as deficient in the 1970 survey.

(ii) As with the leaves some 12% of the soil samples were deficient in P, which represents a decline of about 5% when compared with the situation in 1970. The Nottingham system showed the highest incidence of deficient samples (18%) while the Umzinto coast lowlands showed the lowest incidence (10%). The Nottingham system contained the largest proportion of moderately to strongly P fixing soils (43%) followed by the Komatipoort (29%) and Umzinto midlands (22%) soil systems.

(iii) Rating of N mineralization potential indicated that on average N release from soils in the Nottingham system was the highest, followed by the Komatipoort and Umzinto (midlands and coast lowlands) and Berea system.

(iv) Mean soil pH values ranged from a low of 5,1 for the Nottingham, to a high of 6,7 for the Komatipoort system. In general, there was little change in the average pH values for the various systems compared to those obtained in 1970.

(v) Mean values for Ca and Mg in the various regions were generally much lower than those obtained in 1970. Of the 13% of samples that were deficient in Ca, just under half of the soils were classified as Red Recent sands with the balance shared equally between the Grey Recent sands and TMS (ordinary) soils. The samples deficient in Mg were also largely confined to these parent materials with an average of 10% being deficient in Mg.

(vi) Based on a threshold value of 20 ppm, just under half of the soil samples analysed were rated as marginal to deficient in S. This is well in excess of the numbers showing leaf S deficiency. Soils of the Umzinto coast lowlands and Komatipoort systems were most frequently low in S, particularly when derived from granite, TMS (ord) and sandy alluvium.

(vii) Based on a threshold value of 0,5 ppm Zn for sandy soils, about 7% of all samples analysed were deficient. More than half of these deficiencies occurred in the Umzinto coast lowlands and were associated mainly with TMS (ord) and Recent Sands. Using a 1,0 ppm threshold value for soils with more than 15% clay, 22% of the samples were marginal to deficient in Zn. These deficiencies were confined mainly to soils derived from Swazi Basic Rocks and dolerite in the Komatipoort system.

By extension area

Some of the most important results were as follows:

Nitrogen

Leaf analysis revealed a moderate incidence of N deficiency in the Zululand North (27%), Zululand South (26%), North Coast (20%), South Coast (23%) and Lower South Coast (23%) areas. Swaziland (6%), Midlands North (6%) and Midlands Central (4%) were the areas which were least deficient.

Since the 1980–82 sampling period there has been a slight increase in the number of samples deficient in N, rising from an average of about 10% (1980–82) to 15% for the 1986–88 period. Extension areas showing the greatest increase in N deficiency include the Eastern Transvaal (from 1 to 28%) and North Coast (from 12 to 26%) while areas that showed a decline in N deficiency included the Midlands South (from 26 to 8%) and South Coast (from 27 to 21%). Only small changes were noted for the remaining areas.

Table 3

Mean soil analytical values for the main bioclimatic regions

Natural Region	Soil system	N mineralization category	Soil acidity		Phosphorus		Exchangeable bases			Other	
			pH (H_2O)	Ex Al Index (ppm)	Truog P (ppm)	PDI	K ppm	Ca ppm	Mg ppm	S ppm	Zn ppm
Coast Lowlands	Berea	1	5,5	11	35	0,59	119	686	141	35	1,7
	Umzinto	2	5,5	16	32	0,61	122	694	157	21	1,6
Coast hinterland	Umzinto midlands	2	5,2	31	29	0,60	104	387	104	24	2,0
Mistbelt	Nottingham	4	5,1	51	33	0,48	121	411	114	47	2,1
Lowveld	Komatipoort	3	6,7	13	35	0,53	194	1 571	363	24	1,7
Threshold values				81	10	0,20	112* 150**	150	25	20	0,5† 1,0††
Percentage of deficient samples			1980 to 1988	8	12	11	51* 56**	13	4	50	7† 22††
			1971	9	17	–	40	10	5	1	12

* Clay content 30% or less
** Clay content more than 30%
† Clay content less than 15%
†† Clay content 15% and over

Areas that showed the largest proportion of samples with a low to moderate N mineralization potential (N categories 1 + 2) included the Lower South Coast (90%), South Coast (85%), Zululand South (80%) and North Coast (80%) areas. Cane areas with the highest proportion of samples with high to very high N mineralization potential included Pongola (81%), Midlands South (81%), Eastern Transvaal (73%), Midlands North (71%) and Swaziland (68%). The magnitude of these differences is consistent with the different nature and distribution of soil parent materials between these areas.

The observed incidence of N deficient leaf samples in each area is fairly consistent with the proportion of soil samples rated as having a low to moderate N mineralizing capacity in each area. In general, areas with more than 60% of low to moderate N mineralizing soils were associated with an incidence of 20% or more N deficiency. It is known that since 1980 there has been a marked decline in the average consumption of N fertilizer in the sugar industry (Thompson[9]). Under these circumstances crops growing on category 1 and 2 N mineralizing soils are most likely to exhibit N deficiency.

Phosphorus

1. Whilst leaf analysis generally indicated a fairly low incidence of P deficiency (12%) throughout the industry, this should be viewed against a rising trend in the proportion of samples deficient in P. Since the 1980/82 period the level of P deficiency has doubled, rising from 7% to 15% for the 86/88 period.
2. Cane areas showing the greatest increase in percentage of leaf samples deficient in P since 1980/82 include Midlands North (from 10 to 24%), Zululand Central (from 9 to 27%), Pongola (15 to 26%) and Swaziland (2 to 14%). On the other hand areas showing a build-up in average soil P levels include Midlands South (from 29 to 58 ppm), Midlands Central (from 16 to 25 ppm), Umfolozi (from 38 to 49 ppm) and KwaZulu (from 10 to 19 ppm).
3. In terms of the P supplying power, soils were least deficient when derived from Red (4%) and Grey (6%) recent sands, while the highest incidence of P deficiency occurred in soils derived from Swazi Basic Rocks (24%), TMS mistbelt (18%) and dolerite/basalt (17%). An assessment of PDI values showed that soils in these three groups were also moderately to strongly P fixing, tending to reduce any residual P treatment effects.

Potassium

1. Leaf analysis for potassium deficiency showed that the Eastern Transvaal (53%), Swaziland (43%), Pongola (30%), Umfolozi (30%) and Durban North Coast (30%) areas were the most deficient. However, a comparison of the frequency distribution of leaf K for the different sampling periods suggests a general improvement in K uptake for most areas.

   The areas that showed the greatest decline in K deficiency between 1980/82 and 1986/88 included the Eastern Transvaal (from 60 to 35%), Zululand South (from 41 to 24%) and North Coast (from 27 to 20%). Comparative soil K data for these areas also confirmed an upward trend in the average K levels since 1980/82. However, in some areas the incidence of K deficiency based on leaf analysis appeared to increase, the biggest increase occurring in Swaziland (from 38 to 52%), with smaller increases in Pongola (from 30 to 36%) and Zululand North (from 10 to 22%).
2. Leaf analysis can also be used for diagnosing luxury consumption of K when levels are in excess of 1,5% K. On average only about 12% of the samples analysed during the 1980/88 period contained excessive K. However, in some areas there was a clear indication of luxury consumption and these included Midlands Central (27%), Midlands North (26%) and Midlands South (21%). Available soil analytical data from these areas suggests a similar trend, with each area showing an above average proportion of samples with more than 245 ppm K.

Conclusions

Considering that since 1984 there has been a 12% decline in fertilizer use within the sugar industry (Ranwell[7]), it is reassuring that the results of this survey indicate that there are no large scale nutrient deficiencies, apart from potassium. As in the 1970 survey, this nutrient was found to be the most frequently limiting, based on both leaf and soil analysis. The incidence of K deficiency in the irrigated areas is particularly high and use of additional K fertilizer may be justified on certain soils. These include the heavier textured Shortlands, Bonheim and Arcadia form soils. The threshold value for K in these soils was recently raised from 150 to 225 ppm, which will assist in determining more reliably the K requirement of mainly irrigated cane. The merits of introducing seasonal and varietal correction factors for leaf K are also being investigated.

In a number of extension areas the ratio of the number of soil to leaf samples submitted was well in excess of 3 to 1, suggesting that there is room for more intensive leaf sampling, particularly where there is a high proportion of low to moderate N mineralizing soils. The large imbalance in S deficiency values that was apparent between soil and leaf analyses also suggests that the present threshold value of 20 ppm for S in soils is too high, and that a value of 15 ppm would be more appropriate for advisory purposes.

The results presented in this paper demonstrate the potential value of a computer data bank based on soil and leaf analyses. In future, the Extension Service of the Experiment Station will be better acquainted with soil fertility trends for individual extension areas, particularly when sufficient information at soil form level becomes available. A knowledge of changes in nutrient availability, for example, may be useful in evaluating the effects of fertilizer use as part of a situation survey in an extension area. A number of growers now use the Field Record System (FRS) and a link up with the FAS data bank would enable a grower to assess the performance of his fields in relation to soil and leaf analysis.

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