APPLICATION OF THE DRIS APPROACH FOR CALIBRATING SOIL AND PLANT FACTORS IN THEIR EFFECTS ON YIELD OF SUGARCANE

By E. R. BEAUFILS and M. E. SUMNER

Department of Soil Science and Agrometeorology, University of Natal, Pietermaritzburg

Abstract

Beaufils' experimental approach and calibration technique with a formula (DRIS for Diagnosis and Recommendation Integrated System) is applied to sugarcane cultivation. Provisional norms for soil pH, P, K, Ca, Mg and plant N, P, K, Ca and Mg are presented in the form of indices. They all are derived from a single general formula. The steps followed for establishing these norms, by interpreting data supplied by growers in the South African sugar industry, are described. An application of these indices to an independent N P K lime factorial pot experiment is then analysed. In this experiment, diagnoses from both "DRIS" and "threshold value" techniques are compared, as also are the yield responses obtained by application of the treatments which would be recommended. Although still provisional, the DRIS indices presented in this paper show for each nutrient considered a marked superiority for both sensitivity of diagnosis and yield increases, when compared with the "threshold value" technique. The complementary nature of information from both soil and plant for diagnostic purpose is illustrated, as well as the necessity for any diagnostic technique to take into account the "concept of balance" for both soil and plant. The results confirm that diagnoses of nutrient requirements can be determined by the DRIS method irrespective of cane age.

Introduction

The technique and steps followed in order to establish provisional diagnostic indices for sugarcane are as proposed by Beaufils in his DRIS Monograph.[1] His general calibration formula for plant external and internal characters has been applied to the calibration of both the soil and the plant yield and quality factors of the crop.

This technique, which is one of the possibilities offered by the DRIS approach[1 2], is preferred at this stage because information about soil clay contents was not available from the cane growers' files, which were the source of basic data. The results presented in this paper represent a continuation of previous observations on the application of DRIS to sugarcane.[7 8 9]

Provisional soil calibration for pH, K, Ca and Mg

A line was drawn arbitrarily at 5t of cane/ha/month as a provisional limit between two yield populations: a good one grouping all the sites for which the yield was above this value, and a poor one for the sites yielding less. A comparison of some useful characteristics between these two populations can be made as indicated in Table 1.

The DRIS general calibration formula for diagnosing plant and soil requirements is:

$$\text{X index} = \frac{\Sigma\left[f\left(\frac{X}{A}\right)_1 \frac{k}{CV_{(X/A)}} + f\left(\frac{X}{B}\right)_2 \frac{k}{CV_{(X/B)}} \cdots + f\left(\frac{X}{Z}\right)_n \frac{k}{CV_{(X/Z)}}\right] - \Sigma\left[f\left(\frac{a}{X}\right)_1 \frac{k}{CV_{(a/X)}} + f\left(\frac{b}{X}\right)_2 \frac{k}{CV_{(b/X)}} \cdots + f\left(\frac{z}{X}\right)_m \frac{k}{CV_{(z/X)}}\right]}{n + m}$$

(after Beaufils 1973)[1]

TABLE 1

Comparison of means and variances for soil parameters between a cane yielding population considered "good" and another one considered "poor". (All sites selected at random over the sugarcane growing areas in South Africa — information collected from growers' files).

Soil Parameters	Population of "poor" canes			Population of "good" canes			Variance ratio poor/good
	Number of Observations	Mean Value	Variance	Number of Observations	Mean Value	Variance	
pH	2 575	5,8	1,2371	701	5,3	0,8394	1,473**
P ppm	2 325	39	1062,777	595	25	699,669	1,518**
K ppm	2 586	214	30623,18	700	175	13553,5	2,259**
Ca ppm	2 556	1 363	1220990,0	710	854	973366,7	1,254**
Mg ppm	2 457	495	129071,4	681	313	56125,1	2,294**
P/K	2 320	0,278	0,1212525	586	0,206	0,08319	1,457**
Ca/P	2 301	40,986	2151,904	581	41,56	2090,191	1,029
P/Mg	2 204	0,172	0,103422	550	0,197	0,128702	0,803
Ca/K	2 547	8,109	72,20582	681	6,139	77,4326	0,932
Mg/K	2 448	2,602	3,03026	652	2,145	3,56177	0,850
Ca/Mg	2 434	4,625	80,34448	665	3,919	52,6831	1,525**
K/pH	2 566	35,817	723,81	690	33,078	425,81	1,699**
P/pH	2 316	6,684	27,772	590	4,624	21,412	1,297**
Ca/pH	2 539	212,832	21276,25	683	144,342	19140,66	1,111
Mg/pH	2 438	80,695	2983,455	653	58,102	1816,21	1,642**

Degree of significance for variance ratio: ** for $P \geqslant 0{,}01$

This was applied to the data in Table 1 in order to derive the necessary equations for calculating soil diagnostic indices for sugarcane.

In this general calibration formula[1]:

1. A, B, C,....Z and a, b, c,....z represent any internal or external plant yield or quality factor in the form of an organic or inorganic component involved in parameters found to be suitable for diagnosis.

2. $f\left(\frac{X}{A}\right)$ .... and $f\left(\frac{a}{X}\right)$ .... are equal to:

$$100\left[\frac{(X/A)}{\overline{(X/A)}} - 1\right] \text{ and } 100\left[\frac{(a/X)}{\overline{(a/X)}} - 1\right]$$

whenever the actual value found for a suitable parameter X/A (or a/X) is higher than the general mean value $\overline{X/A}$ (or $\overline{a/X}$) and $f\left(\frac{X}{A}\right)$ .... and $f\left(\frac{a}{X}\right)$ .... are equal to:

$$100\left[1 - \frac{\overline{(X/A)}}{(X/A)}\right] \text{ and } 100\left[1 - \frac{\overline{(a/X)}}{(a/X)}\right]$$

whenever the actual value found for a suitable parameter X/A (or a/X) is lower than the general mean value $\overline{X/A}$ (or $\overline{a/X}$);

$f\left(\frac{X}{A}\right)$ .... and or $f\left(\frac{a}{X}\right)$ .... are equal to zero whenever the actual value found for X/A (or a/X) is equal to the general mean value $\overline{X/A}$ (or $\overline{a/X}$).

3. $CV_{(A/X)......}$ and $CV_{(a/x)......}$ represent the respective coefficients of variation found for X/A (or a/X) characterising any population taken as a reference, i.e. either the population of normally developing plants, or the population of good yielders, or the population of good yielders developing normally, or any other population taken as a reference to suit any diagnostic purpose.

4. "k" is a sensitivity coefficient, the value of which is arbitrarily chosen (1, 10, 20, etc.) to suit the purpose.

Note that in this general calibration formula[1]:

(*a*) the number of functions that constitute the formula is equal to the number of characters considered *minus one* as each character is simultaneously expressed in terms of all the others. The value (n + m) is therefore always equal to the number of functions.

(*b*) the sign in front of each function is positive whenever the character considered is situated in the numerator and negative when situated in the denominator.

(*c*) A, B, C....Z and a, b, c....z all represent dissimilar characters.

Soil DRIS indices for P, K, Ca and Mg can then be calculated, using the parameters found for the population of "good" cane as reference data for means and CV's.

Let us assume that the following values were found from the soil analysis of a site (in fact, the control plot 0000 in the pot experiment analysed later):

P = 27 ppm K = 103 ppm Ca = 121 ppm
Mg = 58 ppm and pH = 4,1

To calculate the function f(P/K):

(*a*) from Table 1:

general mean value = 0,206

$$CV = \frac{\sqrt{0{,}08319} \times 100}{0{,}206} = 140{,}01$$

(*b*) from analysis of the site

P/K = 0,262

(*c*) from convention, k = 10

Since the value found: (0,262) is higher than general mean value (0,206), f(P/K) is given as:

$$f(P/K) = \left[\frac{0{,}262}{0{,}206} - 1\right] \times 100 \times \frac{10}{140{,}01} = 1{,}94$$

because the term $\left[100 \times \frac{10}{140{,}01}\right]$ will remain constant for this particular function, it can be calculated once as 7,14: and for this particular case f(P/K) becomes:

$$f(P/K) = \left[\frac{0{,}262}{0{,}206} - 1\right] \times 7{,}14 = 1{,}94$$

If in another example, P = 25, K = 147, P/K = 0,170 <0,206, then the function f(P/K) becomes:

$$f(P/K) = \left[1 - \frac{0{,}206}{0{,}170}\right] \times 7{,}14 = -1{,}51$$

Taking by convention k = 10 and calculating all the CV's for the "good" population from Table 1, the values of soil P, K, Ca and Mg can be obtained as follows:

$$\text{Soil P index} = \frac{\Sigma[f(P/K) \times 7{,}14 + f(P/Mg) \times 5{,}49 + f(P/pH) \times 4{,}24] - [f(Ca/P) \times 9{,}09]}{4}$$

$$\text{Soil K index} = \frac{[f(K/pH) \times 16{,}03] - \Sigma[(f(P/K) \times 7{,}14 + f(Ca/K) \times 6{,}98 + f(Mg/K) \times 11{,}37]}{4}$$

$$\text{Soil Ca index} = \frac{\Sigma[f(Ca/P) \times 9{,}09 + f(Ca/K) \times 6{,}98 + f(Ca/Mg) \times 5{,}40 + f(Ca/pH) \times 10{,}43]}{4}$$

$$\text{Soil Mg index} = \frac{\Sigma[f(Mg/K) \times 11{,}37 + f(Mg/pH) \times 13{,}63] - \Sigma[f(P/Mg) \times 5{,}49 + f(Ca/Mg) \times 5{,}40]}{4}$$

From the example previously given for the soil analytical data from plot 0000 (P = 27, K = 103, Ca = 121, Mg = 58 and pH = 4,1) the values obtained for the indices become:

P index = 22 K index = 14
Ca index = −38 Mg index = −19

giving for this soil the following order of nutrient requirement:

$$\text{Ca} - 38 > \text{Mg} - 19 > \text{K} + 14 > \text{P} + 22$$

for which the obvious treatment, in a qualitative form, would be (considering soil only), application of dolomitic lime (Ca + Mg), and this is in agreement with the low value of the pH.

As previously mentioned by Beaufils[1 2 3 4 5 6]:

1. The DRIS index values thus obtained for soil requirement calibration reflect the resulting interactions (balance) between all the soil characters considered (here, pH, P, K, Ca and Mg).
2. These index values are related to cane yields because of the degree of significance of the variance ratio for soil parameters included in the formula. Significance for these variance ratios between two populations of "high" and "low" yield, indicates *that a relationship between yield and soil or plant composition is possible and that this relationship with yield can be expressed and exploited to suit diagnostic purposes.*
3. The fact that some parameters involved in the equation show no significance for their variance ratio only diminishes the degree of *sensitivity* of the corresponding index for diagnostic purposes. The more parameters involved in this equation for which variance ratio is significant, the more sensitive the index obtained will be. Incorporation in the calibration formula of such parameters for which the variance ratio is not significant will only have a neutral effect on the significance of the index obtained; this incorporation is nevertheless required in order to get a better assessment of the balance in the soil (or the plant).
4. It is because,
   (*a*) some parameters involved in the calibration formula show no degree of significance;
   (*b*) some general means between populations of "good" and "poor" cane are not always identical
   that the DRIS norms proposed here for sugarcane are given as provisional.
5. For standardizing the calibration of the plant external and internal yield and quality factors f(CV) is used; this makes possible a comparison based on yield or quality between variables for which natural fluctuations as well as analytical precisions can differ sometimes very considerably. It should not be confused with the usual meaning and interpretation given to the value of a CV, as representing the amplitudes of the variations within a given localised experiment, for instance.

Provisional plant calibration for N, P, K, Ca and Mg

Calibration of plant yield and quality factors will follow the same steps as previously done for soil calibration; a qualitative reading from DRIS charts for N P K Ca and Mg will be given.

Application of Beaufils' general calibration formula[1] to the figures in Table 2 on the same principle as previously used for soil calibration will supply the equations for calculating the plant indices for N P K Ca and Mg as follows (k = 10 and CV's from Table 2 population of "good" cane).

$$\text{plant N index} = \frac{\Sigma[f(N/K) \times 47{,}69 + f(N/Ca) \times 35{,}75 + f(N/Mg) \times 37{,}05] - [f(P/N) \times 62{,}58]}{4}$$

$$\text{plant P index} = \frac{\Sigma[f(P/N) \times 62{,}58 + f(P/K) \times 41{,}61 + f(P/Mg) \times 34{,}98] - [f(Ca/P) \times 35{,}35]}{4}$$

$$\text{plant K index} = \frac{-\Sigma[f(N/K) \times 47{,}69 + f(P/K) \times 41{,}61 + f(Ca/K) \times 28{,}85 + f(Mg/K) \times 27{,}66]}{4}$$

$$\text{plant Ca index} = \frac{\Sigma[f(Ca/P) \times 35{,}35 + f(Ca/K) \times 28{,}85 + f(Ca/Mg) \times 31{,}79] - [f(N/Ca) \times 35{,}75]}{4}$$

$$\text{plant Mg index} = \frac{[f(Mg/K) \times 27{,}66] - \Sigma[f(N/Mg)\ 37{,}05 + f(P/Mg) \times 34{,}98 + f(Ca/Mg) \times 31{,}79]}{4}$$

TABLE 2

Comparison of means and variances for plant parameters between a cane yielding population considered "good" (above 5t/cane/ha/month) and another one considered "poor" (below or equal to 5t/cane/ha/month).
(All sites selected at random over the sugarcane growing area in South Africa — information collected from growers' files).

TVD leaf parameters	Population of "poor" cane			Population of "good" cane			Variance ratios poor/good
	Number of observations	Mean value	Variance	Number of observations	Mean value	Variance	
N/K	783	1,587	0,1313774	510	1,511	0,1004268	1,308**
N/Ca	725	7,521	4,913621	486	7,813	4,775009	1,029
N/Mg	723	9,023	6,414725	484	8,607	5,395466	1,188*
P/N	783	0,128	0,000598	511	0,122	0,000380	1,573**
P/K	783	0,201	0,003028	510	0,183	0,001933	1,566**
P/Mg	723	1,144	0,141316	484	1,039	0,088242	1,601**
Ca/P	725	1,153	0,116403	486	1,146	0,105136	1,107
Ca/K	725	0,231	0,009608	485	0,205	0,0050489	1,902**
Mg/K	723	0,188	0,004928	483	0,186	0,004521	1,090
Ca/Mg	723	1,283	0,191406	484	1,158	0,132751	1,441**

Degree of significance for variance ratio: ** for $P \geqslant 0{,}01$
* for $P \geqslant 0{,}05$

In the case of the 3 x 3 x 3 x 3 N P K L factorial pot experiment previously mentioned, corresponding leaf analyses for the 0000 plot were found to be:

N%dm = 1,30 P%dm = 0,29 K%dm = 0,56
Ca%dm = 0,42 and Mg%dm = 0,06

Application of the equations established above in order to calculate the plant indices for N P K Ca and Mg in sugarcane leaves for this control plot gave the following indices:

N = − 6 P = + 62 K = − 40
Ca = + 75 Mg = − 91

and the following order for plant cane requirements:

$$Mg - 91 > K - 40 > N - 6 > P + 62 > Ca + 75$$

Mg is apparently the nutrient most required but *Ca is now found to be excessive in the plant, while it was the most insufficient in the soil* (*see previous section*). This apparently contradictory situation pointed out by Beaufils on several occasions[1 2 3] will be analysed in more detail in the next section.

Direct reading of N P K Ca Mg indices for sugar leaves on linked DRIS charts

The direct reading of nutrient requirements by a plant in terms of comparable functions of yield as a reflection of the interactions within the plant was first established by Beaufils in 1956 for rubber trees in Vietnam.[4 5 6] This reading was achieved by means of a trilinear co-ordinate chart identical to the ones reproduced in Figs. 1, 2 and 3. Readings and linkage between charts by means of arrows have been explained in detail in previous papers,[1 4 5] and more recently in the particular case of N P K requirements for sugarcane.[9]

Using again the leaf analysis figures from plot 0000 of the pot experiment (i.e.: N%dm = 1,30, P%dm = 0,29, K%dm = 0,56, Ca%dm = 0,42 and Mg%dm = 0,06):

(i) reading from PNK chart gives:
N↓ P→ K↓↓
(ii) reading from P Ca Mg chart gives:
P↘ Ca→ Mg↓↓
(iii) reading from K Ca Mg chart gives:
K↓ Ca→ Mg↓↓

Linkage between the three charts gives the qualitative order of plant requirement for these nutrients as:—

$$Mg > K > N > P > Ca,$$

the same order as previously calculated from the equations.

Notes

Points 1, 2, 3, 4 and 5 emphasised in the notes for soil calibration, apply equally to plant calibration.

Moreover a sixth point must be outlined, namely that plant norms involving Ca and Mg are given under reservation, as they correspond to the routine leaf analysis performed on TVD leaves, for cane aged 4 to 9 months, sampled between November and March. *These norms would eventually be confirmed under no age or season restriction only for TVD leaf but not irrespective of sample position.* Indeed, Ca and Mg accumulations in TVD leaf will always be much less accentuated than any accumulation for these same nutrients within a leaf situated at a lower level on the plant, which would automatically be the case for leaf sampled irrespective of position on the plant. Norms can also be established for Ca and Mg (and other nutrients) irrespective of position of sample but usually Ca and Mg are involved in products with N, P and K, as their variations are roughly opposite (Beaufils[1 5 6]).

Application of the proposed norms for soil and plant to independent data supplied by a 3^4 N P K lime factorial trial conducted in pots

Using variety NCo 376, a 3^4 factorial was planted in 25 kg of soil in pots on the 26/11/1974.

The levels were 0,150 and 300 kg N per ha 0,400 and 800 kg P per ha 0,300 and 600 kg K per ha and 0, 3 000 and 10 000 kg dolomitic lime (3 kg Ca $(OH)_2$ for 1 kg MgO) per ha. An overall application of trace elements, viz: 15 kg/ha Cu SO_4 $7H_2O$ + 25 kg/ha Zn SO_4 5 H_2O + 20 kg/ha Borax + 0,5 kg/ha NH_4 molybate, was also applied with every treatment combination.

In Table 3, analytical results are given for both soil and TVD leaf samples corresponding to treatment combinations selected in order to illustrate some steps in a logical sequence relating diagnosis, recommendation and yield response. Corresponding indices calculated on the bases described in the two previous sections are given in Table 4.

Diagnosis from the control plot 0000 shows that the soil requires Ca most and then Mg, while the plant requires Mg most, whereas Ca is present in excess. The correct remedy would be application of Mg without Ca to suit plant demand. As this treatment does not exist, dolomitic lime is considered as in Treatment 0001. The soil requirement for Ca and Mg is supplied as well as the plant requirement for Mg. But this treatment has created a severe imbalance in the plant, where Ca

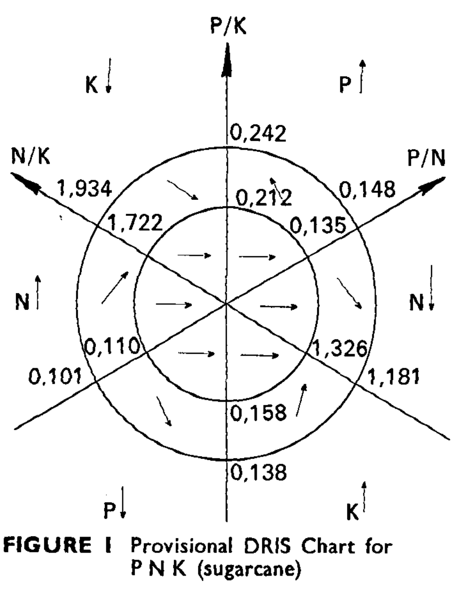

FIGURE 1 Provisional DRIS Chart for P N K (sugarcane)

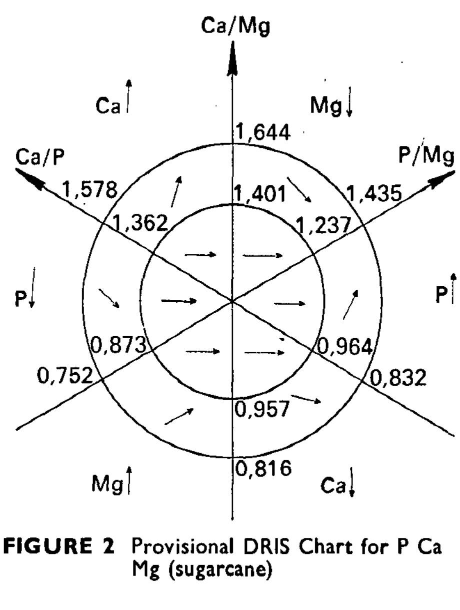

FIGURE 2 Provisional DRIS Chart for P Ca Mg (sugarcane)

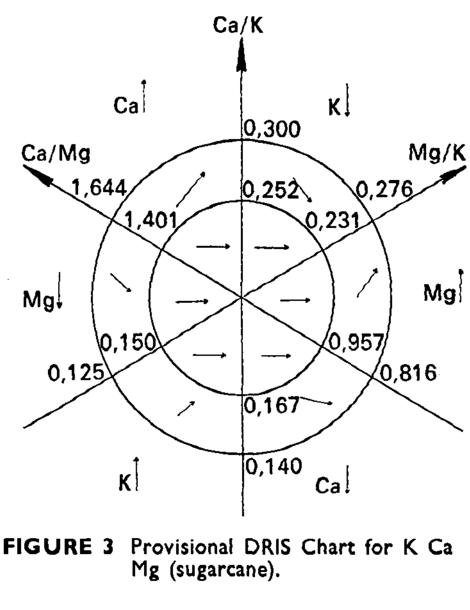

FIGURE 3 Provisional DRIS Chart for K Ca Mg (sugarcane).

TABLE 3

Analytical results for soil and TVD leaf for some treatment combinations of a 3^4 pot factorial planted 26/11/74, sampled 20/10/75. Variety: NCo 376 — Soil Series: Farningham.

Soil and plant analysis on eleven months old cane

Treatments	TVD leaf analysis: d.m%					Soil analysis					Yield
N P K L	N	P	K	Ca	Mg	P ppm	K ppm	Ca ppm	Mg ppm	pH	(grams)
0 0 0 0	1,30	0,29	0,56	0,42	0,06	27	103	121	58	4,10	304
0 0 0 0	0,90	0,37	0,21	0,57	0,24	16	103	780	380	4,80	153
0 0 1 1	1,15	0,29	0,51	0,43	0,18	34	238	740	365	4,60	424
0 0 2 1	1,20	0,13	0,87	0,20	0,03	28	450	785	393	4,65	498
0 0 2 2	0,90	0,27	0,68	0,38	0,16	30	395	1 605	805	6,20	1 040
1 0 2 2	1,15	0,29	0,43	0,44	0,17	27	460	1 670	760	6,00	920
1 1 2 2	1,60	0,24	0,73	0,33	0,14	110	403	1 730	850	6,30	1 150
2 0 2 2	1,30	0,23	0,69	0,35	0,11	18	440	1 600	1 025	6,10	1 390
2 1 2 2	1,20	0,28	0,66	0,37	0,18	132	463	1 815	1 100	6,20	1 016

TABLE 4

DRIS indices corresponding to Table 3

Treatments	TVD leaf analysis					Soil analysis					Yield
N P K L	N	P	K	Ca	Mg	P	K	Ca	Mg	pH	(grams)
0 0 0 0	−6	62	−40	75	−91	22	14	−38	−19	4,10	304
0 0 0 1	−62	128	−236	135	35	−7	−4	0	10	4,80	153
0 0 1 1	−31	41	−56	51	−4	1	6	−5	3	4,60	424
0 0 2 1	32	20	33	44	−130	−5	20	−6	1	4,65	498
0 0 2 2	−50	38	−25	43	−7	−9	8	1	11	6,20	1 040
1 0 2 2	−28	47	−74	59	−5	−12	12	1	10	6,00	920
1 1 2 2	−1	16	−23	24	−17	11	4	−3	6	6,30	1 150
2 0 2 2	−11	22	−21	37	−27	−25	13	1	23	6,10	1 390
2 1 2 2	−27	31	−32	33	−5	13	5	−5	10	6,20	1 016

Most required nutrient underlined twice; second most required nutrient underlined once.

excess has worsened, there is an unsatisfied requirement for K (the second most required nutrient in the plant), and yield has decreased. Diagnosis from plot 0001 shows that the soil is now nearly balanced while the plant is very imbalanced; K is the most required nutrient followed by N. Application of K in treatment 0011 substantially but not completely satisfies the intense plant demand for K. Yield has almost trebled. Note that application of K in this particular case has promoted the taking up of more N by plant.

Diagnosis from plot 0011 shows a similar situation as previously, i.e. the soil is close to balance, whilst the plant requires K, followed by N, but less severely than in plot 0001. A further application of K in plot 0021 completely satisfies K requirement (as well as N). Soil K is now slightly in excess and yield has increased slightly by 17%. Diagnosis from plot 0021 shows a relatively balanced soil but a severe demand for Mg in the plant, provoked by previous treatments. Mg is again supplied to the soil in the form of dolomitic lime. This application, which satisfies almost completely the plant's strong requirement for Mg, more than doubles yield, which increases to 1 040 grams. Diagnosis from plot 0022 shows that P is required to a small extent by the soil, while the plant shows a smaller demand for N and K. Application of N in plot 1022 reduces N requirement but increases the unsatisfied demand for K. Soil demand for P increases slightly and yield decreases slightly.

Diagnosis of plot 1022 indicates conflicting requirements between soil and plant; K and N are the nutrients most required by the plant, whereas P is in excess, while the soil only requires P. In treatment 1122 soil requirements are met with the application of P. In treatment 2022 plant requirements are met with the application of N (K being already a maximum level 2). In treatment 1122 soil P requirement disappears and yield increases by 25%. In treatment 2022, application of N reduces N demand, while promoting the uptake of more K by the plant. Yield increases by 51%. Diagnosis on plot 2022 shows a situation similar to 1022, with a less severe demand for K and N; Mg has now become the nutrient most required. Unfortunately, none of these nutrients (N, K and Mg) were applied in greater quantity, as there were no further levels in the experiment.

Application of P, which is not required by the plant in plot 2122, although there was an apparent soil requirement, makes the unsatisfied plant demand for K and N worse. Yield decreases, confirming the diagnosis on plot 2022. The ideal treatment at this stage would have been application of P to satisfy the soil requirement, complemented by N, K and Mg to satisfy the plant demand. This treatment was not made in the present trial, but the information will be used in further research with the same soil.

It should be noted that the above observations were made possible using the DRIS indices when the cane was eleven

TABLE 5

Compared assessment of both DRIS and threshold value techniques for soil calibration only

Nutrients applied	Yield responses from DRIS diagnosis			Yield responses from threshhold value diagnosis		
	Number of positive responses	Total number of cases the nutrient was recommended	Cumulated yield increases (grams)	Number of positive responses	Total number of cases the nutrient was recommended	Cumulated yield increases
Ca and/or Mg	34	40	+5 277	8	10	+968
K	20	20	+5 988	11	11	+3 055
P	4	10	−456	6	20	−667
Total	58	70	+10 809	25	41	+3 356

months old, which would not have been possible using standard threshold values. This is a distinct advantage of the DRIS system.

Overall estimate of the value of the DRIS diagnosis

An estimate of the relative value of the DRIS diagnosis for soil can be obtained from a comparison of the yield responses to diagnosis made by the DRIS and threshold value approaches (Table 5).

Figures in Table 5 have been obtained by using each treatment combination of the 3^4 pot factorial to represent a field situation. A diagnosis has been carried out using the DRIS system as well as the threshold values, for a soil type on which sugarcane is grown at present in Natal. Threshold values are:

P : 31 ppm; K : 112 ppm; Ca : 150 ppm and Mg : 25 ppm (Mg taken as 75 ppm whenever Ca is less than 150 ppm).

Having made a diagnosis, the yield of the particular plot under diagnosis is subtracted from the yield of the appropriate plot in which a required element was applied to the soil.

This is done in order to obtain an estimate of the magnitude of the yield response which might have been obtained under field conditions. This procedure is carried out for both diagnostic procedures in order to make a comparison. Both the sensitivity of diagnosis and the amplitude of cane yield responses are markedly in favour of the DRIS calibration system as a soil diagnostic tool.

The same process has been repeated using plant calibration alone as a diagnostic tool. The results are presented in Table 6. They indicate that although the age of plant is not the same as that from which the norms were obtained, an even more precise and profitable diagnosis is possible from plant than from soil analyses. A comparison with the threshold value technique is not possible because the threshold values are not applicable to 11 month old cane. A positive yield response to treatments recommended from DRIS diagnosis is observed for 73 out of 78 cases, i.e. 93,5% of the cases diagnosed for which a recommendation could be formulated. A higher yield increase is also observed from diagnosis based on plant data than on soil data. A detailed study shows that in every case where a negative response was observed from a diagnosis based on soil only, the recommendation would not have been formulated had the plant calibration also been taken into account. For example, *there is not one case out of the* 81 *treatment combinations where Ca and/or P is the nutrient most required by the plant.* (Table 6).

Diagnostic technique and concept of balance

A detailed study of this 3^4 pot factorial has drawn attention to the fact that in a large number of cases a positive response

TABLE 6

Assessment of the DRIS calibration technique on plant alone

Nutrients applied	Yield responses from DRIS diagnosis		
	Number of positive responses	Total number of cases the nutrient application was recommended	Cumulated yield increases (grams)
N*	6	8	+1 387
P	0	0	—
K	36	38	+9 786
Ca	0	0	—
Mg	31	32	+6 608
Total	73	78	+17 781

* Had standard threshold values for cane leaf been used, then every plot would have required N which is shown to be erroneous.

could be obtained by application of a given nutrient, although its level in the soil was well above the threshold value (sometimes more than 10 times). As an illustration a few of these cases are presented in Table 7 together with the diagnosis obtained from the DRIS approach. Had such cases been exceptions they would not have been mentioned here, but in fact they represent 58% of the observations in the case of K diagnoses, 79% in the case of Ca diagnoses, and 83% in the case of Mg diagnoses. This observation, which has previously been mentioned for cane leaf analysis by Sumner *et al*,[9] emphasises the necessity for any diagnostic technique to take into account the concept of nutrient balance.

Conclusions

Diagnosis based on the provisional standards proposed here for N P K in sugarcane leaves are essentially the same as those that would be obtained using the DRIS standards developed by the SASA Experiment Station[7], Meyer[8] or Sumner *et al*[9]. The reason for this is that being based on means from a large number of observations, they are unlikely to change appreciably when a different or larger population is studied. These standards have now been extended to Ca and Mg in the plant as well as P, K, Ca and Mg in soil. They already appear to be of general validity, being successfully applied to eleven months old cane, although a reservation is made in the case of Ca and Mg in the leaves. The complementary nature of information that one can gather from both soil and plant for diagnostic purposes is emphasised as well as the necessity for any diagnostic technique to take into account the concept of balance within both plant and soil.

TABLE 7

Comparison of diagnosis and yield responses between the two diagnostic techniques for some cases where the soil figure is well above the threshold value

Treatment combination (original) N P K L	Soil Analysis (ppm)				DRIS indices derived				Yield (original)	Treatment incorporating the nutrient recommended N P K L	Yield after treatment	Yield differences
	P	K	Ca	Mg	P	K	Ca	Mg				
0 1 1 2	93	238*	1 625	1 050	9	−4	−3	14	585	0 1 2 2	804	+219
2 2 0 2	220	265*	1 920	1 050	31	−7	−7	10	173	2 2 1 2	737	+564
0 0 2 1	28	450	785*	393*	−5	20	−6	1	498	0 0 2 2	1 040	+542
1 2 1 1	322	257	1 210*	463*	70	−5	−22	−1	536	1 2 1 2	640	+104
0 1 2 1	170	390	1 020*	393*	35	10	−15	−3	484	0 1 2 2	804	+320
0 2 2 1	400	488	1 280*	428*	82	10	−28	−7	572	0 2 2 2	865	+293

Threshold values are given as follows: P 31 ppm — K 112 ppm
Ca 150 ppm — Mg 25 ppm

* Indicates pertinent values above the threshold values.

Further research work is under way to confirm these observations and to expand the application of the DRIS calibration technique on sugarcane to climatic, field practice and treatment yield factors, as well as for the other essential major and trace elements.

Acknowledgements

The authors wish to thank the Director and staff of the Experiment Station for their co-operation in this project which is being sponsored by the South African Sugar Association. In addition, a very encouraging response was obtained from growers large and small to our request for soil and leaf data together with corresponding yields from their fields. This information has been used to compile the provisional DRIS standards presented here. The authors wish to express their gratitude to the growers for their assistance and co-operation.

The authors also wish to thank Mr Sathiprem Naidoo and the staff of the analytical laboratory at the Soil Science Department, University of Natal, for their assistance in supplying the analytical data from the 3^4 pot factorial.

Special thanks are also due to Mr W. G. Hobbs of Hewlett Packard (Durban) for his help in the programming of the DRIS indices using a pocket calculator.

REFERENCES

1. Beaufils, E. R. (1973). Diagnosis and Recommendation Integrated System (DRIS). A general scheme for experimentation and calibration based on principles developed from research in plant nutrition. Soil Science, Bull. No. 1, University of Natal.
2. Beaufils, E. R. (1975). Calibration of soil and treatment yield/quality factors. Illustration of how the proposed Diagnosis and Recommendation Integrated System (DRIS) is applied. Proceedings 6th Congress, Soil Science Soc. of South Africa (in press).
3. Beaufils, E. R. (1976). Plant/soil/environment calibration (DRIS). 4th International Colloquim on the control of plant nutrition, Ghent, Belgium (in press).
4. Beaufils, E. R. (1956). Mineral equilibrium in the foliage and latex of Hevea Brasiliensis. Ann. INRA Annales Agronomiques. 2.205.
5. Beaufils, E. R. (1959). Physiological Diagnosis. III Method of interpreting the data. Rev. Gen. Caoutch. **36**, 225.
6. Beaufils, E. R. (1961). les déséquilibre chimiques chez l' Hevea Brasiliensis. (Chemical imbalances in rubber trees) La méthode dite du "Diagnostic Physiologicque". Thesis—Paris University (Sorbonne).
7. Experiment Station, South African Sugar Association, Annual Report 1971/72 p. 20.
8. Meyer, J. H. (1975). Advances in the interpretation of foliar analysis of sugarcane in the South African Sugar Industry. SASTA Proc **49**: 129-136.
9. Sumner, M. E. and Beaufils, E. R. (1975). Diagnosis of the N P K requirements of sugarcane irrespective of plant age and season using Beaufils' system (DRIS). Preliminary observations. SASTA Proc **49**: 137-141.