

EFFECT OF TIME OF SAMPLING ON THE DIAGNOSIS OF THE N, P, K, Ca, AND Mg REQUIREMENTS OF SUGARCANE BY THE DRIS APPROACH

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Abstract

A 3⁴ NPK lime factorial experiment is used as a means of testing both soil and leaf norms for sugarcane obtained by the Diagnosis and Recommendation Integrated System (DRIS) developed by Beaufils. Soil and leaf samples were taken from the experiment when the cane was 3, 6, 12 and 18 months old respectively and analysed for a number of essential plant nutrients. The results show that these norms can be validly used in making diagnosis of the N, P, K, Ca and Mg requirements of sugarcane at the four sampling times. Diagnoses by the DRIS approach have the advantage over the threshold value approach in that they can be made over a wide range of ages of material sampled. This is clearly brought out by a comparison of the successes of the two diagnostic techniques. The importance of balance in plant nutrition is emphasized and illustrated by an example on cane lodging. To study balance it is essential to take both soil and plant composition into account simultaneously.

Introduction

One of the main advantages of the Diagnosis and Recommendation Integrated System (DRIS)^{1, 2, 3, 4, 5, 6} for making fertilizer and other treatment recommendations is its ability to make diagnoses irrespective of stage of plant growth and environmental conditions. Past results have indicated that this is likely to be as true for sugarcane^{7, 8, 11, 14} as it has been found for other crops^{1, 2, 3, 4, 10, 15, 16, 17}.

The object of this paper is to test and illustrate this point using both leaf and soil data for sugarcane derived from an NPK lime factorial experiment which showed yield responses to the factors studied.

Experimental procedures

The provisional norms for leaf and soil parameters against which the data from the experiment are compared have been presented previously together with details of the manner in which the DRIS indices are calculated^{7, 8}.

The experiment used for this purpose was a single replication of a 3⁴ NPK lime factorial laid down on Cartref soil series at the Huletts Estate at Darnall. The experiment was fertilized on 23/11/74 and planted on 30/11/1974 using the variety NCo 376. The treatment levels are presented in Table 1.

TABLE 1
 Levels of nutrients applied in factorial experiment

Nutrient	Level		
	0	1	2
N as urea (kg/ha)	0	150	300
P as single supers (kg/ha)	0	400	800
K as KCl (kg/ha)	0	300	600
L as dolomitic lime (mton/ha)	0	3	10

The reason for using such high levels of fertilizer was not to attempt to reach maximum yields but rather to induce imbalances in both soil and plant in order to obtain a better understanding of the relationship between fertilizer applied, its reaction with the soil and the resultant influence on the plant.

Both soil (Mount Edgecombe auger) and leaf (3rd leaf blade) were sampled on each plot four times during the growth of the plant crop. Samples were taken on 28/2/1975 (3 month old cane), 6/6/1975 (6 month old cane), 5/12/1975 (12 month old cane) and 28/6/1976 (18 month old cane). At harvesting on 3/7/1976 yield and sucrose content were recorded. Because the sucrose content did not vary much (13-14%) over all the plots in the experiment only tons cane per hectare has been used as a yield parameter.

Before the start of the experiment the soil representative of the experimental area had the following composition:

P 32 ppm, K 75 ppm, Ca 155 ppm, Mg 98 ppm, Na 60 ppm, SO₄ 277 ppm, EAI 0,45 me%, CEC 4,43 me%, pH (KCl) 4,0 and clay 11%. The DRIS indices corresponding to this analysis, calculated using the norms presently available, gives the order of requirement for the soil as:

$$\text{Ca} - 30 > \text{Mg} - 5 > \text{K} 0 > \text{P} 21$$

Taken together with the low pH value and the toxic level of Al¹², this diagnosis indicates the need for lime. On the other hand P can be seen to be excessive in the soil.

Results

Progressive diagnosis of limiting factors

As has been done in previous cases a progressive diagnosis of the factors limiting growth will be undertaken by starting with a low yielding treatment combination, making a diagnosis based on the soil and leaf indices and then supplying the limiting factor by selecting the treatment combination in which that factor has been applied. This exercise has been carried out at the four sampling periods starting with a different treatment combination in each case to add variety to the diagnosis. Before commencing with this example it is important to emphasize the errors to which single plots in a factorial experiment are subject. This sometimes results in an inconsistent pattern as far as yield is concerned and thus one cannot always expect to obtain an increase in yield in this progressive diagnosis when a limiting factor is applied. Nevertheless this is the only approach one can adopt in testing these norms on their own. However when this is done in comparing two diagnostic systems, for example DRIS and threshold value approaches, this problem is largely eliminated as it applies equally to both.

The leaf and soil indices together with cane yield for the progressive diagnosis at the four sampling times are presented in Tables 2, 3, 4 and 5.

Three month old cane (Table 2)

The plot with which the diagnosis is begun (1000) indicates a soil requirement for Ca and Mg together with a low pH

TABLE 2

Progressive diagnosis of the NPK and lime requirements of sugarcane using DRIS indices for leaf and soil calculated from samples taken when the cane was three months old

Treatment N P K L	Yield TCH	Leaf indices					Soil indices				pH KCl	EAI* me %
		N	P	K	Ca	Mg	P	K	Ca	Mg		
1 0 0 0	56	20	-10	29	10	-48	0	24	-15	-19	4,2	0,28
1 0 0 1	74	7	-4	14	7	-23	7	-2	-16	-2	4,2	0,23
1 0 0 2	69	-6	-4	11	15	-16	3	-10	-13	8	5,0	0,08
2 0 0 2	96	30	-7	26	11	-60	12	-1	-15	-11	4,9	0,03
2 1 0 2	81	11	27	14	-2	-51	44	-18	-25	-1	5,5	0,05
2 1 1 2	93	12	-5	27	8	-42	56	-12	-38	-2	5,3	0,05
2 1 2 2	104	19	-17	40	0	-42	42	-7	-33	-1	5,6	0,05
2 2 2 2	89	19	14	50	7	-90	100	-15	-65	-9	5,4	0,03

* EAI = exchangeable aluminium index¹³.

TABLE 3

Progressive diagnosis of the NPK and lime requirements of sugarcane using DRIS indices for leaf and soil calculated from samples taken when the cane was six months old

Treatment N P K L	Yield TCH	Leaf indices					Soil indices				pH KCl	EAI* me %
		N	P	K	Ca	Mg	P	K	Ca	Mg		
0 0 0 0	54	-18	24	-4	29	-30	7	-7	-16	-3	4,2	0,28
0 0 0 1	60	-16	12	0	16	-13	19	-16	-33	10	5,4	0,03
1 0 0 1	74	-7	3	5	11	-12	16	-16	-20	-7	4,4	0,15
1 0 0 2	69	-13	10	-7	21	-11	23	-43	-19	19	5,5	0,03
2 0 0 2	96	-5	11	4	15	-25	11	-43	-11	10	5,7	0,03
2 0 2 2	85	-11	16	6	19	-29	-2	-4	-10	8	5,3	0,03
2 1 2 2	104	-6	8	11	16	-29	96	-36	-49	-8	5,5	0,03
2 2 2 2	89	-13	5	24	9	-25	82	-26	-56	-11	5,1	0,03

* EAI = exchangeable aluminium index¹³.

TABLE 4

Progressive diagnosis of the NPK and lime requirements of sugarcane using DRIS indices for leaf and soil calculated from samples taken when the cane was twelve months old

Treatment N P K L	Yield TCH	Leaf indices					Soil indices				pH KCl	EAI* me %
		N	P	K	Ca	Mg	P	K	Ca	Mg		
0 1 0 0	50	-2	17	-3	15	-27	203	-57	-64	-86	4,0	0,23
0 1 0 1	67	4	13	0	11	-28	107	-51	-46	0	5,4	0,08
0 1 0 2	71	4	18	-7	5	-20	97	-64	-50	0	6,0	0,01
0 1 2 2	66	-4	9	4	22	-32	24	-16	-21	-1	5,9	0,08
1 1 2 2	84	4	6	-1	7	-16	124	-72	-59	-5	6,5	0,08
2 1 2 2	104	3	12	-3	12	-24	60	-30	-28	-5	5,9	0,03
2 2 2 2	89	9	18	-8	4	-23	147	-84	-56	-8	6,0	0,05

* EAI = exchangeable aluminium index¹³.

TABLE 5
Progressive diagnosis of the NPK and lime requirements of sugarcane using DRIS indices for leaf and soil calculated from samples taken when the cane was eighteen months old

Treatment N P K L	Yield TCH	Leaf indices					Soil indices				pH KCl	EAI* me %
		N	P	K	Ca	Mg	P	K	Ca	Mg		
0 0 1 0	46	7	-5	7	12	-21	6	40	-27	-22	4,1	0,50
0 0 1 1	64	5	-5	10	7	-18	5	-4	-8	0	4,5	0,20
0 0 1 2	78	3	1	-6	16	-8	-1	-21	-2	5	5,1	0,13
0 0 2 2	76	-7	8	7	21	-29	0	-23	-5	3	5,5	0,08
1 0 2 2	77	1	-4	7	6	-10	-1	-5	-11	3	5,2	0,11
1 1 2 2	84	0	1	7	14	-22	89	-26	-54	-20	6,0	0,08
2 1 2 2	104	-7	15	-8	24	-25	27	-22	-17	-5	5,6	0,10
2 2 2 2	89	-3	10	6	16	-29	146	-66	-62	-21	5,6	0,26

* EAI = exchangeable aluminium index¹⁸.

and associated Al. The plant shows a requirement for P and Mg. The treatment to be applied in each case has been indicated by the figures in the table which have been surrounded by a block. Application of the first level of dolomitic lime in plot 1001 results in a yield increase and some improvement in the situation in the soil and plant. However the indices still indicate a requirement for dolomitic lime which is supplied in plot 1002 which does not result in a yield increase. Need for further lime is no longer present although the plant still shows a requirement for Mg. As there are no treatment combinations which would supply further Mg one can resort to the addition of the next most limiting factor. The next logical treatment would be the addition of N which results in a substantial yield increase in plot 2002 with the development of a marked requirement for Mg followed by P in the plant. The soil shows a requirement for Ca and Mg which cannot be satisfied by the treatment combinations available. The only possible treatment which can be selected in this case is P for which the plant shows a requirement but the soil does not. In such cases experience has shown that yield responses are seldom obtained which in this case proves to be true. This treatment (2102) has induced a soil requirement for K while the plant still shows a marked requirement for Mg. The only possible treatment now is K supplied in plot 2112 which raises the yield but does not completely satisfy the soil's requirement for K. When more K is applied a further yield increase is obtained (104 t/ha); although this is a high yielding plot, it still shows a requirement for P in the leaf but not in the soil which has an excessive level. Application of P in plot 2222 results in a substantial yield depression. A yield response in such a case is not to be expected because of the marked nutritional imbalance which results.

Six month old cane (Table 3)

In this case the control plot 0000 has been used as the starting point for the progressive diagnosis which follows a pattern similar to that for the three month old cane and finally reaches the same treatment combination 2122.

Because one is dealing with a dynamic system (soil/plant), one cannot expect all parameters to remain unchanged^{5, 6}. The treatment additions to the soil take varying times to react while the plant is continuously taking up nutrients which may also be disappearing from the labile fraction of the soil in different ways such as leaching, fixation, or volatilization. This is why the sequence of treatment combinations in the progressive diagnosis is not the same as that for the three month

stage. Despite this a meaningful diagnosis has still been possible in this case.

Twelve month old cane (Table 4)

Following the same basic reasoning as for the two cases above the same final point is reached although in this case plot 0100 has been used as the starting point. The one step that requires a little further explanation is that in going from plot 1122 to plot 2122, which involves the addition of N although the plant showed no requirement for this element. Plot 1122 shows excessive P and a requirement for K. Experience has shown that in situations such as this where the pH is high the addition of N leads to a reduction in pH and better utilization of the P already present in the soil^{5, 9}. This is confirmed in this case by a decrease in the index for P from 124 to 60 showing a better utilization.

Eighteen month old cane (Table 5)

In general the situation in this case is comparable to those discussed above and similar reasoning has been used in the progressive diagnosis resulting in the same treatment combination being reached.

Discussion

Bearing in mind that the order of requirement of the soil or plant for a given nutrient is more important than the actual value of the indices⁵, the following conclusions can be drawn from the above data and observations:

- (i) With only two exceptions (plots 0001 and 1002 at six month stage), Mg is always the nutrient most required by the plant at all stages of development. The fact that this requirement by the plant could not be entirely satisfied reduces the sensitivity of the diagnosis because one must select the second most limiting factor as the basis for the treatment subsequently applied in the progressive diagnosis⁵. In practice when making fertilizer recommendations for growers, this problem would not arise because the nature and amount of the various fertilizers can always be readjusted. (It should be noted that this experiment was planted before DRIS norms were available.)
- (ii) Despite the fact that plot 2122 received 10 t/ha of dolomitic lime, the soil shows a requirement for Ca and/or Mg at all sampling times. When the amounts of P and K applied are reduced in plot 2002, there is

TABLE 6
Comparison of threshold value and DRIS approaches to diagnosis of N P K Ca and Mg requirements of cane using leaves sampled at six months

Treatment N P K L	Yield TCH	Leaf composition						DRIS indices						Plot supplying diagnosed limiting nutrient for		Yield recorded as a result of applying limiting nutrient		Yield difference to be credited to	
		N %	P %	K %	Ca %	Mg %	N	P	K	Ca	Mg	DRIS	Threshold value	DRIS TCH	Threshold value TCH	DRIS diagnosis TCH	Threshold value diagnosis TCH		
1 2 2 0	82	1,20	0,22	1,07	0,29	0,10	-16	18	7	24	-32	2221	2220	97	76	+15	-7		
1 2 2 1	81	1,30	0,24	1,17	0,30	0,11	-16	18	8	21	-31	2222	2221	89	97	+8	+16		
0 2 2 1	83	1,30	0,20	1,08	0,26	0,10	-8	11	9	17	-30	1212	1212	92	92	+9	+9		

little change in yield but an improvement in soil balance. This treatment is the most economical in the entire experiment and could have been predicted from the diagnosis based on the soil analysis before the experiment was established which is compared with that for plot 2002 at three and six months below:

	Ca	Mg	K	P	pH	EAI
Original	-30	-5	0	21	4,0	0,45
Plot 2002 (3 months)	-15	-11	-1	12	4,9	0,03
Plot 2002 (6 months)	-11	10	-43	11	5,7	0,03

The above figures show that the N and lime applied has reduced the soil requirement for Ca and Mg, increased the pH, decreased the Al and P excesses and increased the requirement for K.

- (iii) Treatment combinations 0100 and 0010 confirm the diagnosis made on the original soil because both give yield depression below the control plot indicating that P and K are the nutrients least required by the soil.
- (iv) Further confirmation is given by plot 2222 which yields less than 2002 indicating that the balance between the various fertilizer components applied together on the one hand and the particular soil composition on the other is more important than the total quantity applied.

Comparison of DRIS and threshold value diagnostic techniques for leaves only

The technique used previously was adopted once more to compare the two systems of diagnosis. What is done very briefly is to make a diagnosis by both methods using all the plots in the experiment as starting points and then selecting those treatments which supply the limiting nutrients in each case. The difference in yield (either positive or negative) is credited to the appropriate diagnostic technique as illustrated in Table 6. Starting with plot 1220 as an example DRIS diagnosis shows a requirement for both N and Mg which are supplied in plot 2221 which gave a yield of 97 tons/ha thus giving a yield increase of 15 tons/ha which is credited to the DRIS approach. By the threshold value technique using the following critical levels for February 1,6% N, 0,19% P, 1,05% K, 0,15% Ca and 0,08% Mg* only N is limiting which is supplied in plot 2220, giving a yield of 76 tons/ha. Thus a yield difference of -6 tons/ha is credited to the threshold value approach. This process is repeated for all the plots in the experiment as further illustrated in Table 6, using plots 1221 and 0212 as starting points. The sum of the yield differences over all plots gives a relative measure of success of the two approaches in making diagnoses based on leaf analysis only. Such results are presented in Table 7 for both systems

TABLE 7

Comparison of the threshold value and DRIS approaches to diagnosis of N P K Ca and Mg requirements of sugarcane at different stages of growth as measured by the cumulative yield difference as a result of applying the limiting nutrients over all plots of the factorial experiment

Stage of sampling months	Diagnostic Method					
	DRIS			Threshold value		
	Yield difference			Yield difference		
	Positive TCH	Negative TCH	Nett TCH	Positive TCH	Negative TCH	Nett TCH
3	+ 976	-154	+822	+1 218	-102	N/A
6	+1 344	-128	+1 216			+1 116
12	+1 208	- 58	+1 150			N/A
18	+1 323	-142	+1 181			N/A

* As used by FAS of SASA Experiment Station.

at the six month stage and for the DRIS approach at the other sampling times. It must be borne in mind that the threshold value technique can only be used for the six month sampling because the norms are only valid at that stage. The results show that the DRIS approach is slightly superior at the six month stage and that similar yield increments are obtained by this approach at the twelve and eighteen month stages. At the three month stage the yield differences were somewhat smaller. The ability of the DRIS approach to make meaningful diagnoses at all stages of growth is a distinct advantage which can usefully be exploited in the sugar industry.

Plant and soil reactions to treatments applied to the soil

Table 8 summarizes the significant treatment from the analysis of variance for soil parameters. The direction of the effect has been shown using arrows, a vertical arrow denoting an increase and *vice versa*. At all sampling times, application of superphosphate increased the P index in the soil while lime decreased it. These treatments had the opposite effect on the Ca index. As far as the K index is concerned the superphosphate treatment decreased it while KCl had a promoting effect

as expected. An effect which is interesting but somewhat difficult to explain is the increase in S level in the soil brought about by liming. Most of the other significant effects are in agreement with what would be expected⁹.

All the leaf parameters are significantly affected by one or more of the soil treatments (Table 9). In general the responses are consistent at all the sampling periods and are in accordance with expectation. Most soil treatments bring about responses within the plant which are either the result of directly applying the particular nutrient or an indirect result arising from changes in soil pH or nutrient solubility brought about by the treatment.

Lodging and nutrient balance

As mentioned earlier one of the aims of this experiment was to create imbalances in the nutrition of the plant so that the interactions between nutrients and their effect on growth could be studied further. As an example of this some observations on lodging in relation to treatment were made at harvesting. In general N applications promoted lodging as would be

TABLE 8
Summary of treatments which were significant in analysis of variance of soil parameters obtained at the four sampling periods. (Arrows indicate direction of change)

Soil Parameter	3 Month Stage				6 Month Stage				12 Month Stage				18 Month Stage			
	Treatments†				Treatments†				Treatments†				Treatments†			
	N	P	K	L	N	P	K	L	N	P	K	L	N	P	K	L
P Index		↑**		↓**		↑**		↓**	↓*	↑**		↓**	↓*	↑**		↓**
K Index		↓**			↓**		↑**			↓**		↑**		↓**		↓**
Ca Index		↓**		↑**	↓**			↑**		↓**		↑**		↓**		↑**
Mg Index				↑**				↑**				↑**				↑**
Na ppm													↑**			
S ppm		↑**				↑**				↑**				↑**		
CEC me %	↓*			↑**				↑**		↑**				↑**		↑**
pH (KCl)				↑**				↑**		↑**				↑**		↑**
Al me %	↑*	↓*		↓**				↓**	↑*	↓*		↓**	↑*	↓**	↓**	↓**

† In addition to the elements listed as treatments the following elements were also applied:
 P = P + S + Ca, K = K + Cl, L = Ca + Mg
 * = significant at 5% level.
 ** = significant at 1% level.

TABLE 9
Summary of treatments which were significant in analysis of variance of leaf parameters obtained at the four sampling periods. (Arrows indicate direction of change)

Leaf Parameter	3 Month Stage				6 Month Stage				12 Month Stage				18 Month Stage			
	Treatments†				Treatments†				Treatments†				Treatments†			
	N	P	K	L	N	P	K	L	N	P	K	L	N	P	K	L
N index	↑**	↓*	↑**	↓**	↑**	↓*	↑*	↓*	↑**	↓*	↑*	↓*	↑**	↓*	↑*	↓*
P index		↑*				↑**				↑**				↑**		
K index			↑**		↑*		↑**	↓**	↑*	↑**		↓**		↑**		↓**
Ca index			↓**	↑**				↑**		↓**		↑**		↓**		↑**
Mg Index		↑*		↑*		↑*	↓*	↑*		↑*		↑*		↑*		↑*
S %	↑**	↑**			↑**	↑**			↑**	↑**						
Cl %			↑**		↑**		↑*		↑**		↑*					
Fe ppm				↓**				↓**				↓**				↓**
Zn ppm	↑*	↓**	↓**	↓**			↓**	↓**				↓**			↓*	↓**
Mn ppm				↓**			↓**	↓**	↑*			↓**				↓**
Cu ppm			↓*		↓*		↓*	↓**				↓**				↓**
Si %		↑**		↓*		↓*	↑**			↑**		↑**	↓**			↑**
Moisture %	↑*	↑**			↑**	↑**				↑**		Not Analysed				

† In addition to the elements listed as treatments the following elements were also applied:
 P = P + S + Ca, K = K + Cl, L = Ca + Mg
 * = significant at 5% level.
 ** = significant at 1% level.

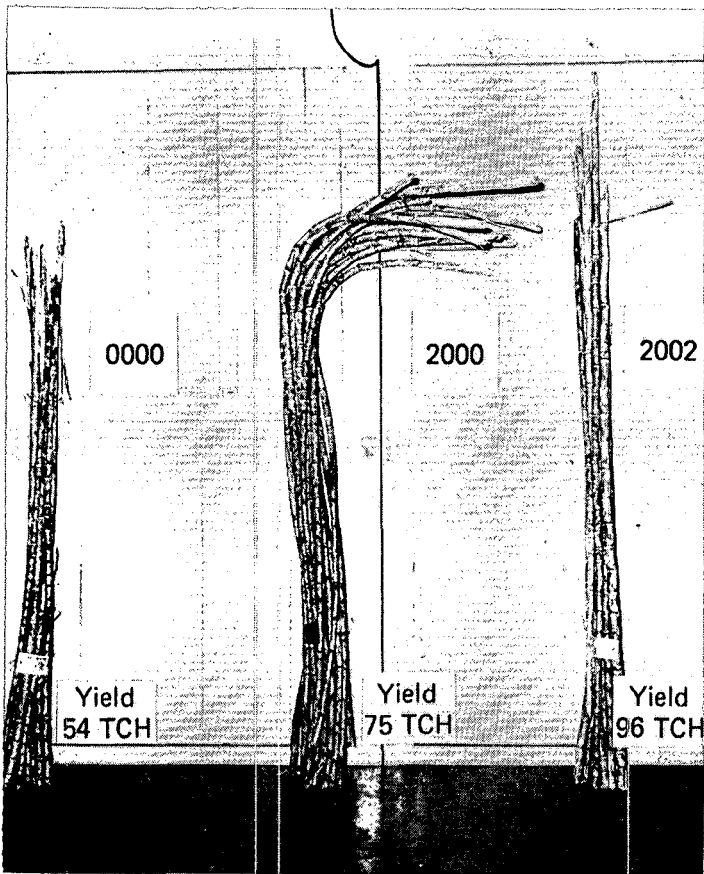


PLATE 1a: Illustration of the effect of nutritional balance on cane lodging.

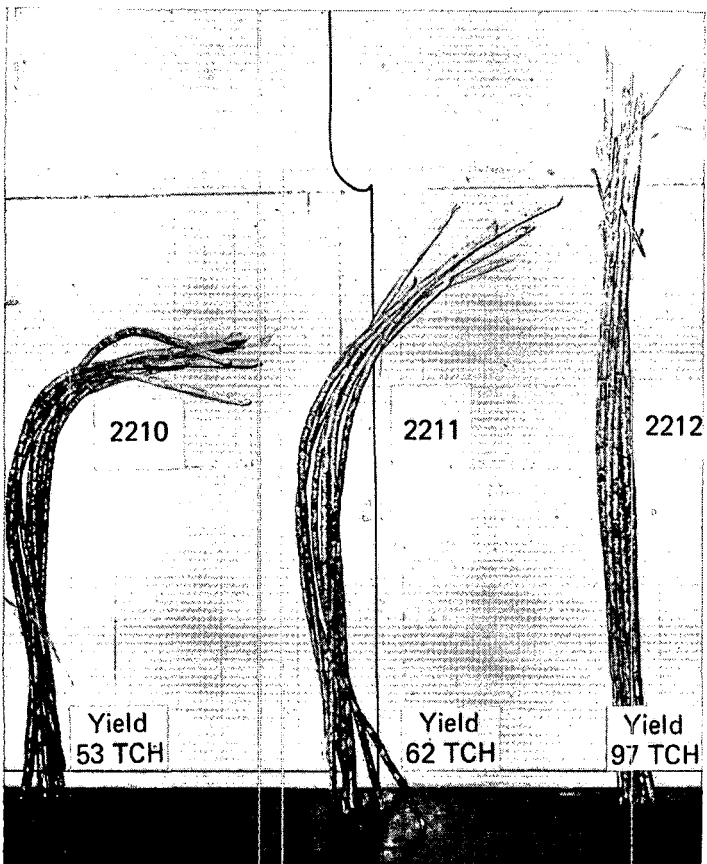


PLATE 1b: Illustration of the effect of nutritional balance on cane lodging.

expected. However liming counteracted the adverse effect of N as illustrated in Plate 1a and b. In both cases liming de-

creased lodging while increasing yield. Unfortunately this observation was made after harvesting had begun so that on this experiment a complete set of data is not available. However on three other experiments ratings of lodging have been made so that this effect can be studied in greater detail in the future.

Conclusions

It has been demonstrated that the DRIS approach has an advantage over the threshold value approach to diagnosis in that the former can be used to make valid diagnoses based on leaf and soil parameters throughout the growth of the crop. This is very important in practice as it makes it possible to sample the crop over a greatly extended period.

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