THE DETERMINATION OF NITROGENOUS FERTILIZER REQUIREMENT
OF SUGARCANE CROPS BY FOLIAR DIAGNOSIS

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INTRODUCTION

One of the major problems facing the agronomist is the evolution of suitable procedures so that practical advice may be given on fertilization of sugar cane crops produced on large fields of any plantations or sectors of sugar estates.

The use of soil analysis or even of field trials fails to solve the problems facing the cane grower. He knows from observation that the conditions met with in his fields are quite specific because of the particular varieties, climate and soils involved. The soils have often been altered by previous treatments and by management practices preceding those in current use.

Plant analysis, or more precisely, foliar diagnosis, based upon 20 years' research and application fulfills this first requisite more than any other since the desired information is collected on the growing crop.

Though foliar diagnosis is free from any major defects, it offers difficulties in adequate and representative sampling of the leaves and the final interpretation leading to the formulation of fertilizer requirements. However, these difficulties have been overcome by proper organization coupled with continuity in experimentation.

To start with, periodic leaf sampling must be done in order to cover the right stages during the growth cycle. Furthermore, mean values of the nutritional indices over a number of years constitute the only sound basis for nitrogen fertilization with un-irrigated canes or with plantations located in climates affected by wide atmospheric fluctuations.

It seems most essential, as far as nitrogen is concerned, to calibrate leaf contents for each recommended variety against net sugar responses obtained in an extensive series of field trials replicated in "space and time". This more refined adjustment is dictated by both physiological and economical considerations, nitrogen being probably the most active and mobile, yet fugitive and expensive, of the three major nutrients N, P and K.

It is necessary to review briefly the rules and precautions put forward and followed in foliar diagnosis work in Mauritius, based on the author's experience since 1936, and extended later to Reunion and Madagascar islands.

(a) The third leaf punch sampling technique is quite safe, easy and cheap. It allows as many samples as are needed.

(b) Green weight of leaf blades collected for punching provides additional information of great value especially in fertilizer trials on which the form and amount or method of placement of fertilizer are being studied in relation to their nutritive effect.

(c) Normally leaves should be sampled on ratoon canes only on 2 or 3 occasions between the age limits of 4 to 6 months when the crop is in full vegetative growth during the wet summer period well before flowering occurs. The samples need bulking prior to chemical analysis as a single sample may be misleading. It must be noted that
ratoons are usually harvested at approximately 12 months during the drier and cooler period.

(d) No sampling should be attempted on canes suffering from drought or from the ill effects of cyclones resulting in shredded leaves and in growth setback. Crops suffering from obvious diseases or pests should also be excluded.

(e) Accurate, yet rapid and inexpensive, methods of analysing properly dried leaf punch samples are now available. A single wet combustion with hydrogen peroxide and sulphuric acid is employed: N being determined directly by nesslerisation, P by coeruleo-molybdate and K is determined by means of the flame photometer for large number of samples or, otherwise, by the newly developed and convenient tetraphenylborate volumetric procedure.

(f) No truly reliable advice on fertilization is possible, for Mauritius conditions at least, unless foliar diagnosis data have been collected systematically for 2 or preferably 3 years on the same location. A safe rule is to rely on 3 years' moving averages for leaf punch N, P and K.

(g) Foliar diagnosis should normally include the 3 major nutrients N, P and K.

(h) Within limits, leaf punch N, P and K are independent of one another. The application of a nutrient, whilst it may affect its own level in the leaf, does not alter that of the others.

(i) Once foliar diagnosis control has been firmly established, it has to be continued on a permanent basis as a follow-up procedure.

(j) Optimum ranges for leaf punch P and K of new varieties can be obtained by comparing the leaf contents in regular variety trials against a standard variety for which the optimum ranges are already known.

(k) The nutritive effect of nitrogen as disclosed by the leaf during vegetation is not followed in the same proportion by the productive effect obtained at cane harvesting for different varieties. Leaf punch optimum values and the need for nitrogen have, therefore, to be worked out directly for each major variety recommended for a broad regional unit. The procedure proposed for assessing this last requisite is the subject of the present communication.

EXPERIMENTAL

The first series of post-release variety-nitrogen trials, conducted in Mauritius, was started in 1954, on 6 un-irrigated locations and run according to the following plan:

<table>
<thead>
<tr>
<th>Locations</th>
<th>6</th>
<th>Altitude 60-1500 ft. Annual rainfall 60-130 in. Soil types four.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varieties</td>
<td>6</td>
<td>N. 134/32 (standard), Ebene 1/37, B. 3337, B. 34104, B. 37161 and B. 37172.</td>
</tr>
<tr>
<td>Nitrogen levels</td>
<td>3</td>
<td>Low (20 kg N/arpt), Medium (40) and High (60).</td>
</tr>
<tr>
<td>Individual replication</td>
<td>2</td>
<td>Early, medium and late.</td>
</tr>
<tr>
<td>Years</td>
<td>4</td>
<td>Total plot reapings 2592.</td>
</tr>
</tbody>
</table>

As leaf sampling was done twice on each plot for the 6 varieties in 1955, 1956, and 1957, and for only 2 varieties (B. 37172 and Ebene 1/37) in 1958, some 4750 samples, each consisting of 40 blades, were collected.
All data for both leaves or canes used in the following discussion are averages for the 3 ratoons. The years 1956 and 1957 were excellent for both cane tonnage and quality, whereas 1958 suffered from two mild cyclones which adversely affected some varieties, especially Ebène 1/37.

Two varieties emerged from these trials and have been recommended for the following environmental conditions:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Location</th>
<th>Altitude</th>
<th>Annual Rainfall</th>
<th>Soil Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. 37172</td>
<td>a, b, c, d</td>
<td>50-600 ft.</td>
<td>60-80 in.</td>
<td>two</td>
</tr>
<tr>
<td>Ebène 1/37</td>
<td>c, d, e, f</td>
<td>300-1500 ft.</td>
<td>70-130 in.</td>
<td>three</td>
</tr>
</tbody>
</table>

The pending problem was to determine the correct N fertilization in the locations where those varieties grow well. Average responses to nitrogen fertilization, high level (60 kg N/arpt) compared with low level (20 kg N/arpt), are shown in Table I. The CCS % cane calculated in the laboratory has been reduced by 20% to conform with values normally obtained in the sugar factories.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>AVERAGE RESPONSE TO NITROGEN, CCS % CANE AND TONS CCS/ARPT (1 arpent = 1.04 acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All locations</td>
<td>Locations suited to B. 37172</td>
</tr>
<tr>
<td>Variety</td>
<td>CCS % C</td>
</tr>
<tr>
<td>M. 134/32</td>
<td>-0.56</td>
</tr>
<tr>
<td>B. 3337</td>
<td>+0.09</td>
</tr>
<tr>
<td>B. 37172</td>
<td>-0.23</td>
</tr>
<tr>
<td>Ebène 1/37</td>
<td>-0.51</td>
</tr>
</tbody>
</table>

These data show clearly that sugar cane varieties react quite differently to the same nitrogen fertilization: extremes being B. 3337 and B. 37172 on the one hand, for which CCS % cane is not appreciably altered at harvest, and M. 134/32 and Ebène 1/37 on the other, for which CCS % cane values are greatly lowered. The first group of varieties has comparatively light foliage, high fibre content and an erect growth habit, whereas the other group of varieties possesses heavy foliage, much lower fibre and lodges more easily.

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>AVERAGE FOLIAR DIAGNOSIS DATA FOR TWO VARIETIES AT TWO NITROGEN LEVELS COMPARED TO OPTIMUM FOLIAR DIAGNOSIS VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. 37172</td>
<td><strong>Locations:</strong> a, b, c, d</td>
</tr>
<tr>
<td>20 kg N/arpt</td>
<td>60 kg N/arpt</td>
</tr>
<tr>
<td><strong>Leaf punch N</strong></td>
<td>1.78</td>
</tr>
<tr>
<td><strong>P₂O₅</strong></td>
<td>0.45</td>
</tr>
<tr>
<td><strong>K₂O</strong></td>
<td>1.46</td>
</tr>
<tr>
<td><strong>Optimum</strong></td>
<td>1.72</td>
</tr>
<tr>
<td><strong>Ebène 1/37</strong></td>
<td><strong>Locations:</strong> c, d, e, f</td>
</tr>
<tr>
<td>20 kg N/arpt</td>
<td>60 kg N/arpt</td>
</tr>
<tr>
<td><strong>Leaf punch N</strong></td>
<td>1.64</td>
</tr>
</tbody>
</table>
A summary of the average foliar diagnosis data is given in Table I for the low and high levels of nitrogen fertilization.

The values observed for P and K in the series of trials are within the accepted optimum ranges for the 2 varieties, indicating that the basic P and K fertilization used was adequate.

An example is given below to illustrate the procedure adopted to calculate the data used in the final interpretation.

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>-20 kg N/arpt</th>
<th>Difference</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf punch N</td>
<td>1.70</td>
<td>1.85</td>
<td>+0.15</td>
<td>1.85 × 100 = 108.8</td>
</tr>
<tr>
<td>Leaf green weight</td>
<td>18.8</td>
<td>20.9</td>
<td></td>
<td>20.9 × 100 = 111.2</td>
</tr>
<tr>
<td>(in g)</td>
<td></td>
<td></td>
<td></td>
<td>108.8 × 111.2 = 121.0 or 21%</td>
</tr>
<tr>
<td>LPN x GLW (%)</td>
<td>4.175</td>
<td>4.591</td>
<td>+0.416</td>
<td>100</td>
</tr>
</tbody>
</table>

In order to calculate the net sugar response, it is necessary to subtract from the difference (gross response) the price equivalent of 20 kg N or 100 sulfate of ammonia, which is the standard dose used throughout. In the case under consideration, this amount works out at 0.080 tons CCS which must be subtracted from 0.416 to give a net response of 0.336 tons CCS per arpent.

For each variety, B. 37172 and Ebène 1/37, there are 24 sets of data available corresponding to the standard dose of 20 kg N/arpt, thus enumerated:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>1.94</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locations</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>20 to 40 kg N/arpt</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>40 to 60 ,,</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Harvesting dates</td>
<td>3</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>

DISCUSSION

Ten regression equations (Table III) have been worked out for n = 24. FDₙ₁ corresponds to an initial leaf punch N, and FDₙ₂ to that resulting from an additional standard dose of 20 kg N/arpt.

Figs. 1 and 2 have been prepared from data obtained for B. 37172 and Ebène 1/37, respectively, in using the appropriate equations 1, 4 and 5 given above.

They show for B. 37172 (Fig. 1) that, following nitrogen fertilization, no positive changes are to be expected in leaf punch N after 2.05 has been reached, in leaf punch N x green leaf Wt. after 2.00, and in net sugar response after 1.94, this last figure corresponding to the optimum leaf punch N.

For Ebène 1/37 (Fig. 2), extra nitrogen fertilization will bring no changes in leaf punch N after 2.20, in leaf punch N x green leaf Wt. after 2.12, and in net sugar response after 1.74, this last figure corresponding to the optimum leaf punch.

It follows that the productive effect (net sugar response, equation 5) is not far off the nutritive effects (leaf content and green weight equations 1 and 4)—as far as B. 37172 is concerned, whilst the productive effect falls short of the nutritive effects by a large margin with Ebène 1/37. In other words, if by over-fertilization the maximum leaf punch nitrogen of 2.05 is reached with B. 37172, instead of the optimum 1.94, a financial loss of more than 0.200 tons of CCS/arpent would be expected to result. On the other hand, with Ebène 1/37 reaching the maximum of 2.20 instead of
TABLE III

RELATIONS BETWEEN LEAF PUNCH NITROGEN AND LEAF AND SUGAR RESPONSES FOLLOWING FERTILIZATION WITH 20 KG N/ARPHT

<table>
<thead>
<tr>
<th>Equation</th>
<th>Relation</th>
<th>t. values</th>
<th>Ebbne 2/37</th>
<th>t. values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equation 1:</td>
<td>Increase in Leaf Punch N = 0.965 - 0.471 FD$_b$</td>
<td>5.06**</td>
<td>0.478 - 0.217 FD$_b$</td>
<td>2.33*</td>
</tr>
<tr>
<td>Equation 2:</td>
<td>Leaf Punch N = 0.965 + 0.539 FD$_b$</td>
<td>5.06**</td>
<td>0.478 + 0.783 FD$_b$</td>
<td>2.33*</td>
</tr>
<tr>
<td>Equation 3:</td>
<td>Initial Leaf Punch N = 1.8903 FD$_b$ - 1.8241</td>
<td>5.06**</td>
<td>1.2771 FD$_b$ - 0.61045</td>
<td>2.33*</td>
</tr>
<tr>
<td>Equation 4:</td>
<td>% increase Leaf Punch N x Green Leaf Wt. = 128.23 - 64.0 FD$_b$</td>
<td>5.98**</td>
<td>57.02 - 26.9 FD$_b$</td>
<td>4.06**</td>
</tr>
<tr>
<td>Equation 5:</td>
<td>Net sugar response Tons CCS/arpent = 2.09925 - 1.54 FD$_b$</td>
<td>3.32**</td>
<td>1.807 - 1.09 FD$_b$</td>
<td>2.96**</td>
</tr>
</tbody>
</table>

* Regression coeff. significant to 0.05 level.
** Regression coeff. significant to 0.01 level.

Fig. 1: Variety 37172. Relation between initial leaf punch nitrogen and (i) increases in leaf punch N (plain line), (ii) % increase in leaf punch N x leaf green weight (broken line) and (iii) net sugar response (dotted line) following a standard application of 20 kg N per arpent.
the optimum 1.74, a financial loss of at least 0.600 tons of CCS per arpent could follow. This probably constitutes the major shortcoming of the otherwise excellent Ebène 1/37 variety which, unless receiving the right amount of N fertilization in its recommended locations, is liable to suffer substantial losses. Over-fertilization is to be avoided as Ebène 1/37, when subjected to cyclonic winds, suffers from shredding of its tender big leaves, and from cane lodging or breakage of stalks during the grand season of growth.

Fig. 3 shows nitrogenous fertilizer requirement to reach the optimum leaf punch nitrogen of 1.94 for B. 37172 and of 1.74 for Ebène 1/37. The curves have been drawn by starting from the optimum (nitrogen requirement nil) using step by step equation 3 (Table IV) for inferior leaf N values and equation 2 for superior leaf N values.
The total nitrogenous fertilizer requirements for each of the 6 locations covered in the series of trials under consideration are given in Table IV as determined from the curves shown in Fig. 3. The initial leaf punch N (no N fertilization) has been obtained from equation 3, starting with the lower level of nitrogen fertilization tried (20 kg N/arpent).

<table>
<thead>
<tr>
<th>TABLE IV</th>
<th>NITROGENOUS FERTILIZER REQUIREMENT OF TWO VARIETIES AT FOUR SELECTED LOCATIONS FOR EACH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Locations</strong></td>
<td><strong>B. 37172</strong> (Opt. N. 1.34)</td>
</tr>
<tr>
<td></td>
<td>Initial</td>
</tr>
<tr>
<td></td>
<td>Leaf Punch N %</td>
</tr>
<tr>
<td>c</td>
<td>1.33</td>
</tr>
<tr>
<td>a</td>
<td>1.54</td>
</tr>
<tr>
<td>b</td>
<td>1.58</td>
</tr>
<tr>
<td>d</td>
<td>1.79</td>
</tr>
<tr>
<td>e</td>
<td>1.68</td>
</tr>
<tr>
<td>f</td>
<td></td>
</tr>
<tr>
<td>Averages</td>
<td>1.56</td>
</tr>
</tbody>
</table>

It is evident from Table IV that nitrogenous fertilizer requirements may fluctuate considerably within the broad region suited to a given variety. Thus for B. 37172, the requirements may vary from 27 to 59 kg N/arpent, and for Ebhne 1/37, between 0 and 56 kg N, although flat rates of fertilization allocating 30 to 40 kg N are common practices in Mauritius.

In the two locations (c and d) suited to both varieties, the nitrogenous fertilizer requirement was found to differ very little for B. 37172 and Ebhne 1/37, though the cash return from the operation would favour B. 37172. As expected, it appears that location exerts a much more dominating influence on the nitrogen requirement of sugar cane than do varieties, at least when the latter are giving comparable total returns.

There is need to emphasize the fact that, by definition, the higher the nitrogenous fertilizer requirement (location c for instance) the greater will be the profit per unit area of cane cultivated.

**DISCUSSIONS**

J. L. du Toit (S. Africa): The experiment was conducted in 6 different situations with 6 varieties. Mr. Halaïs refers to the results of 2 varieties and he has apparently discarded several sites because he refers to 4 sites. In the end he refers to B. 37172 as the cane for low-lying areas with a lower rainfall and for Ebhne as the cane for the higher rainfall and altitude. Then he comes to the conclusion that there is a varietal difference in the amount of nitrogen that is required and in the leaf optimum. I wonder whether that is really a varietal difference or whether it is a difference due to rainfall, other climatic factors and to position. In fact, I would also like to know whether these 2 varieties, the one suited to high altitude, the one to the low altitude, whether all the results were carried out for each situation. If not, then I am afraid we cannot have an inference on varietal difference.

P. Halaïs (Mauritius): I don’t think that you can separate the variety with the suitable environments. There were 6 environments that were chosen for the experiment and 6 varieties. Out of the 6 varieties only 2 have been selected as the best suited varieties, 1 for 4 locations, the other for 4 locations. What we are concerned with is not actually the variety itself as something independent, but we are concerned with a variety in its suitable environment. The other places were discarded because the variety was not doing well, and the other varieties were discarded because they were beaten by these 2 other varieties.