ADVANCES IN SUGARCANE FERTILIZATION IN CUBA

J. Alomá, H. Pérez and I. Cuéllar
Sugarcane Research Institute, Academy of Sciences, Cuba

ABSTRACT
Research in Cuba over the last 5 years, on soils representative of different sugarcane regions, amounted to a total of 101 trials including 214 harvests, and the results presented here lead to the following conclusions:

a) There is generally no significant response when N fertilizer is applied to plant cane but, if there is a response, recommended doses should not exceed 75 kg N/ha. In ratoon crops, responses are obtained by using 100 — 150 kg/ha.
b) There is only a slight response to applications of P, mainly because of the high fixation capacity of most sugarcane soils.
c) From the 1st ratoon onwards, there tends to be a response to K at 100 — 150 kg/ha.
d) Agrotechnical practices related to application influence the results.
e) Filter mud at 100 metric tons/ha has produced positive results.

INTRODUCTION
Cuba is located in the tropical climate belt and has an annual temperature ranging from a mean of 20°C in January to a mean of about 29°C in August. It presents a considerable radiation balanceamounting to almost 80 kilocalories per cm² each year.

The annual rainfall cycle defines the seasons: the dry season from November to April, and the wet season from May to October. The relative humidity ranges from 60% during the day to 90% at night.

The soils are fertile, although the upper layer is usually heterogeneous and complex. The main soil types, in which sugarcane is generally planted, are:

1) the red ferralitic soils
2) the yellow ferralitic soils
3) the brown sialitic soils
4) the dark, plastic, montmorillonitic soils.

The main characteristics of these soils have been detailed by Shishov and Villegas89 (unpublished).

Sugarcane is grown throughout Cuba’s most level areas and occupies two-thirds of the territory. The extensiveness of the area and the variability of conditions for sugarcane on the Island make the application to particular zones of the results of investigations complicated and onerous. Endeavours have been aimed mainly at defining levels of NPK which should be applied. In some instances it has been possible to make specific recommendations for certain cane regions, such as Oriente North Coast and Las Villas, because of the amount of work which has been done in these regions and the uniformity of their principal ecological characteristics.

On account of variations in fertility, the red ferralitic and the brown sialitic soils show considerable heterogeneity in their responses to applications.
of nutrients. In such cases, various general aspects may suggest means of improving the present levels of fertilization. Table 1 shows the response of sugarcane to nutrient levels studied in trials conducted throughout the Island.

MATERIALS AND METHODS

The present work is a summary of the results of 101 trials, including 214 harvests, in representative soils of different cane zones, the uniformity of which had previously been verified.

For NPK trials, factorial designs, randomised blocks and latin squares were used; others were designed only as randomised blocks. In many trials, field observations were made, as well as soil and foliar analyses, to assist in interpreting the results.

The main analytical methods used were the following:

**Soil:** pH in water and 1 N KCl. Soil-solution relationship = 1:2.5.

Exchangeable cations:
- Acids soils—1N ammonium acetate extractive solution, pH 7 Carbonated soils, for Na⁺ and K⁺, ammonium solution Schmuk method for Ca²⁺ and Mg²⁺, NaCl extractive solution, pH 6.5.

Capacity for cation exchange:
- Mehlich’s method

Humus:
- Tiurin’s method

Organic matter:
- Walkley and Black’s method

Total nitrogen:
- Kjeldahl

Hydrolysable nitrogen:
- Tiurin-Knnonanova’s method

Phosphorus:
- Acid soils — Bray-Kurtz’s method. Carbonated soils — Olsen’s method.

**Plant tissue:**

Nitrogen was determined by Kjeldahl’s method. From initial digestion aliquot parts were taken for assessing P by colorimetry through the yellow-metavanadate complex; and potassium, by flame photometry.

RESULTS AND DISCUSSION

**NPK levels and agrotechnical application**

a) **Nitrogen**

1) **Grey-yellowish soils and clayey, carbonated brown sialitic soils**

These closely related soils occupy extensive areas in Oriente province. The grey-yellowish subtype is involved in the dark, plastic montmorillonite type, being highly plastic and readily compacted. Its humus content ranges between 1.42 and 2.98%, and total nitrogen between 0.14 and 0.248%. The carbonated, brown subtype belongs to the brown sialitic type, being highly plastic and readily compacted. Its humus content generally exceeds 3% and the total nitrogen ranges between 0.16 and 0.19.

These soils have seldom shown a response to nitrogenous
fertilization in plant cane, and when this has occurred the levels have ranged from 35 to 70 kg/ha. They tend to show responses in ratoons (Alomá⁴) when 70 to 100 kg/ha of nitrogen is applied.

### TABLE 1. Percentage response of cane to NPK applications (0.05 level).

<table>
<thead>
<tr>
<th>Elements</th>
<th>Red ferralitic and yellow ferralitic soils</th>
<th>Dark brown montmorillonitic soils</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant cane</td>
<td>1st ratoon</td>
</tr>
<tr>
<td>N</td>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>P</td>
<td>16</td>
<td>25</td>
</tr>
<tr>
<td>K</td>
<td>17</td>
<td>21</td>
</tr>
</tbody>
</table>

2) **Clayey, gleyed yellow ferralitic soils**

This subtype, classified with the yellow ferralitic type, is characterized by hydration, presenting difficult moisture conditions and retaining high levels of mobile magnesium. Its humus content ranges between 2.10 and 2.58% and total nitrogen between 0.14 and 0.17%.

From the results of experiments, Fanjul¹⁴ recommends the following levels of N:

<table>
<thead>
<tr>
<th></th>
<th>kg N/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant cane</td>
<td>60-80</td>
</tr>
<tr>
<td>First ratoon</td>
<td>160</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>110-120</td>
</tr>
</tbody>
</table>

The low cane yield obtained from these soils makes fertilizer application prohibitive from the second ratoon onwards.

3) **Red ferralitic and yellow ferralitic soils**

For these soils the results of many experiments carried out on different subtypes were grouped. The complexity of the extensive area which they cover, together with the close relationship between them, makes it advisable to analyse the results as a whole, by soil type, since fertilization of these soils depends upon such conditions as saturation rate, formation of concretions, etc.

Their humus content ranges between 2.66 and 3.17%, total nitrogen between 0.11 and 0.24%.

In these soils, the response to nitrogen in plant cane has been very restricted but, in ratoons, the best results have followed applications of between 100 and 150 kg/ha (Alomá⁴). The numerous particular conditions affecting fertilizer treatments make a general recommendation difficult at present.

4) **Black plastic soils**

This subtype is representative of the dark plastic soils, having a high density, compacting readily and forming a very hard surface layer. It changes considerably with different amounts of water and presents management difficulties.

Plant cane in this soil shows a trend in response from 150 kg
N/ha upwards. In ratoon crops, highly significant responses are given by applications of 50 kg/ha or more.

**Timing of nitrogen applications**

Experiments on various different soils have shown that total nitrogen applied early is as effective as the same amount in 2 or 3 separate dressings. When the plant is well supplied with soil nitrogen, there will be no response to applications, even when the dose is split (Pérez et al). The effects of weather and soil conditions appear to influence the results of fertilization more than splitting the dressing. It has often been noticed that responses to nitrogen in the same soil may vary from year to year. A disadvantage of splitting heavy dressings of nitrogen is that this may result in lowering juice quality.

**Influence of nitrogen on juice quality**

Results have shown that apart from late N applications, those higher than 100 kg/ha can reduce the sucrose of cane by amounts of about 5%. In the red soils, at levels near 100 kg, there is a slight decline in sucrose content. It is more striking in the dark, montmorillonitic ones, the characteristics of which are more unfavourable.

**Nitrogen carriers**

The effects of urea, ammonium nitrate and ammonium sulphate in different doses (up to 200 kg N/ha) and at different times of application, under unirrigated conditions, in red ferrallitic and in grey-yellowish plastic soils, were studied. No significant differences between the carriers were noticed for yield, the choice being dependent upon production costs, storage charges, handling operations, etc. (Alomá et al, Agnarica). When the cane plant was well supplied with nitrogen from the soil, none of the carriers was effective, regardless of levels used and times of application. Late applications resulted in a drop in sucrose, irrespective of the carrier.

**b) Phosphorus**

1) **Grey-yellowish, plastic soils and clayey, brown carbonated soils**

Analyses of such soils by Olsen's method have shown the presence of mere traces or very low amounts of P, but there is no response to applications. Menéndez and Arzola, from foliar analyses, reported values below the critical levels established by investigators in other countries. Alomá et al ascribed the lack of response to the presence of large quantities of calcium carbonate, with fixation of the added phosphorus.

2) **Red ferrallitic soils and yellow ferrallitic soils**

A small response has been obtained from phosphoric fertilization in plant cane and 1st ratoon. An acceptable response is generally obtained from the 2nd ratoon, with optimum values ranging between 75 and 100 kg P/ha. One of the most troublesome conditions occurring in these soils is their high fixation capacity, due
to their high iron and aluminium content. Villegas\textsuperscript{31} reports that the surface horizon relationship, $\text{SiO}_2/R_2\text{O}_3$, in these soils influences the fixation capacity inversely, the fixation power of the sesquioxide being demonstrated. Arzola\textsuperscript{10} emphasises the importance of the iron concretions in these soils, and points out that responses usually occur in soils with a high concretion content, rarely in the typical ones, showing the importance of the form in which the iron is present. Villegas\textsuperscript{31} and Arzola\textsuperscript{10} have shown, in both the laboratory and the field, that fixation in the red ferralitic soils decreases as the applied phosphate level increases.

3) Clayey, gleyed yellow ferralitic soils

In experiments, no responses were obtained after applying P, possibly because these soils rapidly fix large quantities of phosphates.

4) Black, plastic montmorillonitic soil

No significant responses have, so far, followed applications of P.

Sources of phosphorus

Trials comparing finely ground phosphate rock with treble superphosphate, gave the following results:

In red ferralitic soils with a pH of 5 (Alomá\textsuperscript{4}) application of 400 kg/ha of phosphate rock at planting produced the same results as 150 kg/ha for the overall period, in a P deficient soil with a high phosphorus fixing capacity. Broadcast application of phosphate rock on the surface, followed by turning under by means of a harrow, gave better results than strip application at a depth of 50 cm. Gandoy\textsuperscript{15} showed that the application of 90, 180 and 210 kg P$_2$O$_5$/ha as phosphate rock to gleyed, yellow ferralitic soils with an exchangeable H$^+$ of 3 m$\text{e}$/100 gm soil, gave the same results as 60 or 120 kg P$_2$O$_5$/ha as superphosphate applied by hand.

c) Potassium

The soils of Cuba generally have a high K content and slight responses are found in plant cane and first ratoon. Nevertheless, definite trends in response have been detected whenever consecutive harvests are carried out on the same soil, and greater usage of N takes place.

1) Grey-yellowish, plastic soils and clayey, carbonated brown soils

No responses to K have been noted (Alomá\textsuperscript{4}). This may be ascribed to the fact that K is present in sufficient quantities for sugarcane.

2) Red ferralitic soils and yellow ferralitic soils

Applications of K to these soils, also, produce only a slight increase in the plant cane and 1st ratoon (Alomá\textsuperscript{4}) but with a response trend from the second ratoon onwards. There is also a definite trend in favour of higher levels of K, generally from 100 kg K$_2$O upwards (Table 2).

3) Black plastic soils

No increase has been achieved by additional K in these soils,
TABLE 2. K content in soil.

<table>
<thead>
<tr>
<th></th>
<th>Mg / 100 g soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonated brown soils</td>
<td>20.2 - 42.0</td>
</tr>
<tr>
<td>Dark plastic soils</td>
<td>14.4 - 54.0</td>
</tr>
<tr>
<td>Red ferralitic soils</td>
<td>15.0 - 67.7</td>
</tr>
<tr>
<td>Gleyed yellow soils</td>
<td>6.6 - 26.8</td>
</tr>
</tbody>
</table>

in either plant cane or first ratoon, but a significant response trend is observed from the 2nd ratoon onwards.

d) Agronomical aspects influencing fertilization

1) Placement

   Results obtained by Pérez\(^{17}\) have shown that the most rational placement is near the most active zone of root uptake, at a depth of 8–10 cm.

2) Fertilization and cultivation

   Casamayor\(^{11}\) studied the interactions of fertilizers and various methods of weed control by means of heavy applications of nutrients and the use of herbicides. The most satisfactory results were obtained by moderate fertilization and more effective weed control. It should be pointed out that, as long as fertilization increases, weeds develop more vigorously and call for more effective control.

Filter mud

Applications of this sugar industry by-product to various soils in different regions have had beneficial results. In grey-yellowish plastic soils and carbonated brown soils, the following have been observed (Fig. 1):

1) Increases in sugar yield up to 30%;
2) Residual effect of applications over a 5 year period;
3) The application of inorganic fertilizers becomes unnecessary;
4) Decrease in the amount of cultivation required.

It is recommended that 100 metric tons/ha be applied, preferably on the trash, and filter mud direct from the factory has given the best results. On red ferralitic soils (Arzola\(^{15}\)) results overlapped the above rate.

This material has high N and P contents, but relatively low K. (Table 3).

Foliar analysis showed that P from filter mud was more readily available than P from inorganic sources. Since the low K content may restrict the benefits of filter mud in soils with a K deficiency, it is advisable to supplement it with K from some other source (Alomá\(^{8}\)).

Heavy applications, especially over 100 t/ha may have a harmful effect on juice quality.

TABLE 3. NPK content in filter mud.

<table>
<thead>
<tr>
<th>Cane harvested on</th>
<th>N</th>
<th>P(_2)O(_5)</th>
<th>K(_2)O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red ferralitic soils</td>
<td>3.28</td>
<td>2.56</td>
<td>0.45</td>
</tr>
<tr>
<td>Grey soils and dark plastic soils</td>
<td>3.50</td>
<td>4.20</td>
<td>0.40</td>
</tr>
</tbody>
</table>
Establishing fertilizer indices

Although these investigations go back 20 years, research on aspects influencing fertilizer indices is quite recent. The method is close to those employed in Mauritius, Jamaica and Guyana and is aimed at developing more sensitive indices for fertilizer recommendations. Research is also being undertaken on the field record method (Amaral1). So far the results are as follows:

a) Influence of time of day on the sugarcane leaf sample
Pérez and Menéndez19 showed that the period of least variation was between 6.00 and 8.00 a.m., but this does not allow much time for sampling. Between 8.00 and 10.00 a.m. relative humidity drops and air temperature rises. This results in a decrease in plant moisture and a wider variation in N and P levels so that the precision of analysis is reduced. The period between 11.00 a.m. and 5.00 p.m. allows greater scope for sampling under more or less uniform conditions.

b) Assessment of NPK in different parts of the leaf
Fanjul12 records that nitrogen gradually increases in concentration towards the apex of the leaf, and that a section from the centre towards the apex is very uniform. He found that P values did not differ significantly in the leaf sections which he studied, although the content
decreased slightly as the dewlap was approached. The concentration of K in the leaves became lower towards the apex, but there was a more or less uniform zone between the centre and the apex. He recommended selecting samples from centre to apex and discarding the base.

c) Foliar indices

Trials with sugarcane in grey-yellowish soils and carbonated brown soils (Menéndez and Arzola\textsuperscript{16}) have shown a critical level for N, by the TVD method, of 1,80\% (Fig. 2). This level agrees with that reported in Jamaica and Guyana. In these soils it has been noted that the leaf N increases with the dosage of fertilizer N. The lack of response in such soils has made it impossible to establish indices for nitrogen.

In gleyed, yellow ferralitic soils, Fanjul\textsuperscript{13} found that there was no response to nitrogen when the leaf contained more than 1,75\% N. With rates of 0,19\% for leaf P, no response is to be expected from applications up to 80 kg P\textsubscript{2}O\textsubscript{5}. When the leaf P is below 0,16, there is a response to applications of 40–80 kg/ha.

When leaf K is below 0,75\% there is a response to applications of 100 kg K\textsubscript{2}O/ha. Above 1,25\%, no response to K has been noted.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Relationship between increase of percentage of sugar per ha with the fertilization and nitrogen percentage of control.}
\end{figure}
CONCLUSIONS

When the size of the Cuban sugarcane region, and the complexity of its soils are considered, it is obvious that the number of trials so far carried out is very limited, both for conclusive recommendations and for the establishment of reliable fertilizer indices. Nevertheless we can make the following general suggestions, although they apply exclusively to the grey-yellowish soils and the clayey, carbonated brown soils:

**Rates of application**

In the grey-yellowish soils, possible responses to fertilizer in plant cane are limited, the level of adequacy being between 35 and 70 kg N/ha. In ratoons, 70 to 100 kg N/ha may be recommended but the use of P and K is not advised.

In the gleyed, yellow ferralitic soils 60–75 kg N/ha may be recommended for plant cane, 150 kg/ha for 1st ratoon and 110–120 for second ratoon. It is not advisable to apply fertilizers from the 3rd ratoon onwards because of decreasing effects on cane production. Because of lack of response, P and K should not be applied.

Because of fertility or physico-chemical characteristics, the results achieved in these soils do not permit the establishment of precise recommendations. This is particularly true in plant cane in which the response to fertilizers is slight. For ratoons, the following levels may be recommended:

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>First ratoon</td>
<td>100</td>
<td>50–75</td>
<td>100–150</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>100–150</td>
<td>50–100</td>
<td>100–200</td>
</tr>
</tbody>
</table>

It should be borne in mind that applications of over 100 kg N/ha may adversely affect juice quality.

In ferralitic soils with a pH of 5.5 and hydrolytic acidity of 3 me H/100 g soil, 400 kg/ha of phosphate rock may be applied and soluble forms of P are not required during the first 3 crops.

REFERENCES

4. Alomar, J. (1972). Recomendaciones de fertilización para el área de los centrales que bordean la Bahía de Nipe. Memoria 40 Conferencia ATAC.
AVANCES SOBRE LA FERTILIZACIÓN DE LA CAÑA DE AZÚCAR EN CUBA

J. Alomá, H. Pérez y I. Cuéllar

RESUMEN

Se presentan los resultados obtenidos en las investigaciones sobre fertilización en Cuba durante los últimos cinco años, en suelos representativos de diferentes regiones cañeras, en un total de 101 experimentos con 214 cosechas, donde se manifestaron principalmente los siguientes resultados:

a) Generalmente no se logran resultados significativos en la fertilización nitrogenada en caña planta. Cuando se obtiene respuesta, las dosis recomendadas no deben ser superiores a 75 kg/ha. Se obtiene respuesta en los retoños con dosis entre 100 y 150 kg/ha.

b) Existe poca respuesta a las aplicaciones de fósforo debido principalmente al fuerte poder de fijación de la mayoría de los suelos cañeros.

c) El potasio tiende a dar respuesta a partir del primer retoño a niveles de 100 — 150 kg/ha.

d) Las medidas agrotécnicas en la aplicación tienen influencia sobre los resultados obtenidos.

e) Se han logrado resultados positivos con la aplicación de 100 tm/ha de cachaza.