EFFECT OF LIMING ON THE PRODUCTION OF SUGARCANE AND ON THE FERTILITY OF THE SOIL IN THE STATE OF PERNAMBUCO

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ABSTRACT

An experiment using red-yellow latosol soil from the Southern Pernambuco sugarcane plantation zone was conducted in pots, to find out the effects on the dry sugarcane matter and soil fertility from the liming levels corresponding to 3.56 (Al = 0 meq); 1.40 (Al = 0.5 meq); 1.04 (Al = 1.0 meq) and 0.64 (Al = 1.5 meq) t/ha of Ca(OH)$_2$.

The effect of liming on the dry matter production of the aerial part of the sugarcane was confirmed. In the roots, in spite of the decrease of the liming level, no significant statistic was detected.

The different levels of Ca(OH)$_2$ decidedly influence the absorption of Ca and Mg by the aerial part of the cane. The liming increase caused the elevation of the Ca and Mg contents and the saturation of the bases and reduced the Al and H contents of the soil. With the exception of P, the extreme values were obtained with 3.56 t/ha of Ca(OH)$_2$.

The correlations between t/ha of Ca(OH)$_2$ vs $(\text{Ca}^{2+} + \text{Mg}^{2+})$ meq and t/ha of Ca(OH)$_2$ vs Al$^{3+}$ meq on the soil were significant at the coefficients for $(\text{Ca}^{2+} + \text{Mg}^{2+})$ meq and negative for Al$^{3+}$ meq, though both were equal in absolute value.

INTRODUCTION

The sugarcane cultivation in the State of Pernambuco is restricted to two distinct zones: Northern zone and Southern zone. The two zones have sufficiently distinct soil characteristics, topography and climatic conditions. The Southern zone, being the most traditional area for Gramineae cultivation,
presents a very irregular topography, high rainfall and most of its soil falls into the classification of having horizon B latosol (not hydromorphic), where by means of the process of lateritization, the convertible bases and the silica that are not removed from the arable layer by washing (Ayres\textsuperscript{1}), remain as the acid forming agents.

This becomes more evident when the analytical parameters revealed by the soil analysis are known and where they reveal average high contents of Al\textsuperscript{3}\textsuperscript{+}, and low contents of Ca\textsuperscript{2}\textsuperscript{+} and Mg\textsuperscript{2}\textsuperscript{+} as compared with standards for other crop regions. As described, it would be normal that, specifically in this region of sugarcane cultivation, the practice of liming had been a sufficiently representative function in the Graminae cultivation activities.

Inspite of so many evidences, the use of limestone, either to correct acidity or to supply Ca and Mg in the soil, has not yet been rationalized due to a few factors, such as the use of limestone without prior knowledge of its physical and chemical characteristics; the lack of effective methods of incorporation and principally the inexistence of conclusive information about the practice. On the other hand, some producers have used lime of the land for enough time and argue that the practice has increased the number of second harvests of the cane-breaks.

In this light, the importance of liming in these soils can be really justified by the chemical characteristics, by the need to increase the productivity, as well as by the scarcity of fertilizers produced in the region. These assumptions are reinforced by the statement of Kamprath\textsuperscript{7} that soils of humid regions are generally acid in all aspects and that little advantage is obtained from the fertilizers due to the lack of liming, resulting in the low production of the plants.

Laroches\textsuperscript{8}, after consulting various authors, defines liming as a technique of incorporating calcium and magnesium carbonates hydroxides and oxides into the soil in order to increase the supply of calcium and magnesium going to the plant thus correcting the noxious effect of the high acidity.

Kamprath\textsuperscript{7} states that for acid mineral soils, quantities of limestone based on the content of exchangeable Al multiplied by a factor of between 1.5 and 2, would eliminate the principal agent and would promote the elevation of productivity.

For sugarcane, the liming has been a polemic subject all over the world. The results obtained by experimentation with limestone lead to results that to a certain point, are constricting. In certain localities, benefits are obtained with the practice (Ayres\textsuperscript{1}) while in others, liming does not modify the yielding (Ayres\textsuperscript{1} and Cordeiro\textsuperscript{4}). However, information exists that gives sufficient emphasis to limestone as a supplier of calcium and magnesium to the soil; of course, sugarcane would be a little sensitive to the normal contents of exchangeable Al.

One thing that remains perfectly settled is the need to develop wise
programs to define parameters for the use of limestone. Laroche, states that in the tropical countries, the agricultural is superior to industrial production and that 40% or more of their population dedicate themselves to agriculture. Therefore, the adequate use of limestone could become an economic factor, in terms of increasing the potentialities of the soils.

The objective of this present work was to determine the effect of liming on the elimination of exchangeable aluminum, as well as to determine its effect in the production of dry matter in sugarcane.

MATERIALS AND METHODS

A red yellow latosol soil, described by Jacomine et al, from the Barreiros Central Sugar Mill-PE was used for the study of the effect of hydrated lime on the production of dry matter in sugarcane and in the constituents of fertility. Approximately 30 kg. of the upper 20 cm. of topsoil, corresponding to the arable layer, was collected and was packed in plastic vessels with holes in the bottoms for drainage. A mixed sample of soil from the 16 pots was collected and P, K, Ca + Mg, Al and pH were determined according to the methodology described by Vettori. The results obtained are shown in Table 1.

| TABLE 1. Original chemical analysis of the soil |
|------------------|------------|-------|-------|
| P ppm            | K ppm      | Ca+Mg meq/100 ml | Al ppm |
| 3                | 0.06       | 0.10   | 2.40   |

The initial phase of the experiment consisted of laboratory work, where by means of the titration curve the necessary amounts of Ca(OH) 2 were determined for which the 0, 0.5, 1.0 and 1.5 mE levels of Al 3+ in the soil were obtained and which will be considered as the theoretical treatments in the test. The extraction was made with 1N KCl in the proportion of 1:10 (10 ml. of soil:100 ml. of extractor solution). With the quantities determined to control the levels of exchangeable aluminum (Fig. 1), the hydrated lime was homogenized with the 20 cm. of top of each pot, water was added to approximately the field capacity and then they were left to incubate for 30 days.

The CB 45-3 variety was used for the test as it is the type planted most in the region. The shoots with the nodes were treated thermically in a thermal unit at 52°C for 30 minutes, after which the shoots were put in plastic boxes containing washed and sterilized sand to germinate. After 20 days of rooting, 5 plants with their respective nodes were transplanted to each pot. On this occasion, each pot was fertilized with the corresponding value of 30-150-60 kg/ha, respectively of N, P 2O 5 and K 2O, along with 5 kg/ha of Cu, Zn and B. Two fertilizations with 11 and 30 kg/ha respectively, of N and P 2O 5 were made after 30 and 60 days in order to correct the deficiencies of nitrogen.
and phosphorus. This last time, Mg was added to correct the nutrient deficiency, in the proportion of 1:6 (Mg:Ca) of the original content of the soil.

The pots were placed in random blocks, with the 4 treatments repeated 4 times, (Tables 2 and 3) in open sunlight at the PLANALSUCAR Sugarcane Experimental Station in Carpina. After 15 days, the two least developed plants were discarded from each plot, leaving three plants until the end of the tests. Irrigation when necessary, was done manually.

When the plants were 5 months old, they were harvested, separated into the aerial parts and roots, washed and placed in a continuous air circulation oven at 70-75°C to dry until they reached a constant weight. After this, the material was weighed and then ground in a Willey Nr. 20 screen grinder. At the time of harvest, the upper 20 cm of the topsoil from each pot was sampled and the phosphorus and potassium were extracted by the 0.05 N HCl + 0.025 N Na2SO4 solution, the magnesium and aluminum were extracted with 1N KCl solution; and in both cases the proportion of the soil volume: solution volume = 1:10 as described by Vettori11. The determination of H+ was done according to Catani and Jacinto2. The calcium and the magnesium of the aerial part and roots were determined by the methodology described in Sarruge and Hagg10.

RESULTS AND DISCUSSION

Effect on the Dry Matter

The production of the dry matter (aerial part and roots), as well as
the percentage and total contents of Ca and Mg are shown in Table 2. It is shown that the liming caused modifications of the Ca and Mg absorbed (totals) were more accentuated than the percentage of concentrations of the same nutrients. In the first case, the statistical significance was in the 1% probability level. There was no statistical differences shown for the roots.

If we take the exchangeable Al as the indicator of the seed of liming, it is shown that the dosages used were arrived at by multiplying the contents found in the original condition of the soil by 1.05, 0.60, 0.40 and 0.30. This results approaches the information given by Kamprath, in that the multiplying factor would be between 1.5 and 2.5 noting that the maximum production of dry material was obtained with the multiplication factor approximately equal to 1.50.

Considering that the production of dry matter corresponds to 3.50 t/ha of Ca (OH)₂ (Al³⁺ x 1.5) for a good production, it can be observed that the percentage relation between Ca/Mg was approximately 2.8 for the aerial part and 3.8 for the roots. This reinforces the existing knowledge that the Mg is present more in photosynthesizing organs and the Ca in the growth tissues of the radicular system.

With respect to the radicular system, even without statistical proof, there was a tendency for the weight of the roots to increase in the same ratio that the quantity of hydrated lime applied was decreased. The roots with 1.5 meq of Al⁺³ treatment were short, dark and had an inferior appearance.

Effects of the Chemical Properties of the Soil

The liming caused sufficiently accentuated modifications in the chemical constituents of the soil. Shown in Table 3 are significant differences of 1% probability in the contents of Ca + Mg, Ca, Mg, Al, H and V; a 5% probability for P and no significance for K and CEC. The differences were most accentuated for the saturation of the bases with exchangeable aluminum (Al).

All the original characteristics of the exchange complex suffered accentuated modification under the action of the treatments. If it is considered that the CEC of the soil could be obtained by means of the sum of the exchangeable cations of Al, Ca and Mg dislodged by KCl, as Coleman et al. emphasize, this original value was 2.5 meq and the Al x 1.50 treatment corresponds to 4.30 meq, which represents almost a twofold increase. Therefore, for Ca⁺² + Mg⁺² there was an increase of 42 times (4.20 meq to 0.10 meq). Similar results to those obtained here were cited by Laroche and Kamprath for Ca and Mg.

The saturation of exchangeable Al reduced from 93% to 2% by the same process. The original P content (3 ppm) was sufficiently elevated, perhaps due to the additional of phosphorized fertilizers (80 ppm) and association with the short period of cultivation (5 months), and not to the liberation.
<table>
<thead>
<tr>
<th>Ca(OH)$_2$</th>
<th>Aerial Part</th>
<th>Roots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry Matter</td>
<td></td>
</tr>
<tr>
<td></td>
<td>g/pot</td>
<td>%</td>
</tr>
<tr>
<td>35.6</td>
<td>3.56</td>
<td>173.05</td>
</tr>
<tr>
<td>14.0</td>
<td>1.40</td>
<td>149.04</td>
</tr>
<tr>
<td>10.4</td>
<td>1.04</td>
<td>170.76</td>
</tr>
<tr>
<td>6.4</td>
<td>0.64</td>
<td>137.49</td>
</tr>
<tr>
<td>F</td>
<td>6.70*</td>
<td>5.92*</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>26.25</td>
<td>0.06</td>
</tr>
<tr>
<td>CV (%)</td>
<td>8.43</td>
<td>9.05</td>
</tr>
</tbody>
</table>

TABLE 2. Effect of the treatments in the production of dry matter and in the concentrations (%) and extractions (g) of calcium and magnesium in the aerial part and root of the sugar cane plant.
TABLE 3. Effects of hydrated lime in the chemical characteristics of the soil after cutting the sugarcane plant.

<table>
<thead>
<tr>
<th>Ca(OH)$_2$</th>
<th>P ppm</th>
<th>K</th>
<th>Ca+Mg</th>
<th>Ca</th>
<th>Mg</th>
<th>Al</th>
<th>H</th>
<th>CEC</th>
<th>V %</th>
</tr>
</thead>
<tbody>
<tr>
<td>g/pot t/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35.6 3.56</td>
<td>54</td>
<td>0.45</td>
<td>4.2</td>
<td>2.5</td>
<td>1.7</td>
<td>0.1</td>
<td>3.0</td>
<td>7.8</td>
<td>60</td>
</tr>
<tr>
<td>14.0 1.40</td>
<td>85</td>
<td>0.36</td>
<td>1.5</td>
<td>1.2</td>
<td>0.3</td>
<td>1.0</td>
<td>3.9</td>
<td>6.8</td>
<td>27</td>
</tr>
<tr>
<td>10.4 1.04</td>
<td>64</td>
<td>0.36</td>
<td>1.2</td>
<td>0.9</td>
<td>0.3</td>
<td>1.3</td>
<td>4.4</td>
<td>7.3</td>
<td>20</td>
</tr>
<tr>
<td>6.4 0.64</td>
<td>62</td>
<td>0.36</td>
<td>0.9</td>
<td>0.7</td>
<td>0.2</td>
<td>1.6</td>
<td>4.6</td>
<td>7.5</td>
<td>16</td>
</tr>
<tr>
<td>F</td>
<td>5.47*</td>
<td>1.70</td>
<td>68.17*</td>
<td>48.33**</td>
<td>30.76**</td>
<td>101.34**</td>
<td>15.66**</td>
<td>1.31</td>
<td>224.61**</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>22.47</td>
<td>0.16</td>
<td>0.71</td>
<td>0.44</td>
<td>0.48</td>
<td>0.19</td>
<td>0.71</td>
<td>1.36</td>
<td>5.27</td>
</tr>
<tr>
<td>CV (%)</td>
<td>17.03</td>
<td>17.33</td>
<td>19.04</td>
<td>18.05</td>
<td>40.44</td>
<td>12.78</td>
<td>9.28</td>
<td>9.48</td>
<td>8.62</td>
</tr>
</tbody>
</table>
of the P held by the Al, as Kamprath stated. On the other hand, it can be noted that the lowest value of P was obtained in the treatment that received 3.56 t/ha (Al⁺³ x 1.50), and this value statistically differs from the treatments that received 1.40 cm 0.64 t/ha of hydrated lime.

The effect of liming on the levels of exchangeable K in the soil did not cause modification, inspite of known studies that give sufficient emphasis to the Ca/K antagonism. It can be argued that the small quantities of hydrated lime applied were not sufficient to cause this phenomenon.

Studies of Regression

The liming caused modification in most of the chemical characteristics of the soil in question. What really constitutes doubt is exactly the knowledge of the factor that causes reduction of the growth of the plant — if it is the lack of Ca and Mg or the excess of exchangeable Al. Various authors have already made statements in this respect. Lee cultivated potatoes in a nutritive solution and said that 20 ppm of Al in the solution — approximately 3 meq — reduced the growth of the aerial part and of the roots of all the varieties. Evans and Kamprath, in their turn, made distinction between exchangeable Al and Al saturation. The same authors said that corn responds to liming in soils where the aluminum saturation was more than 70%, as well as that a soil only does not respond to liming when the exchangeable aluminum was around 0.40 meq/liter (Approximately 0.04 meq).

On the other hand, some researchers prefer to focalize the liming as the supplier of calcium and magnesium to the plants. Ayres states that for sugarcane, calcium could be considered a limiting factor of growth. Kamprath, in his turn, prefers to attribute the possibility of supplying Ca and Mg, precipitation of Al and Mn, and greater availability for Ca and Mo to liming. He also states that Al affects the assimilation and movement of Ca in the plants.

The regression studies were done with the facts, whose averages are shown in Table 3, precisely to try to identify the factor that best oriented liming. The regression of hydrated lime and Ca + Mg of the soil (Fig. 2) and of hydrated lime and Al⁺³ (Fig. 3) created significant correlation coefficients of 1% probability and were exactly equal to the respective observed values (r = 0.97 and r = -0.97).

The regression between hydrated lime and the saturation index in soil bases (Fig. 4) is created from the two previous regressions, and also gives significance to the 1% probability level (r = 0.99). By what is shown, it becomes difficult to separate the effects of exchangeable Al and Ca²⁺ + Mg²⁺ in the soil on the production, since the material used in the liming — calcium and magnesium carbonates, hydroxides and oxides — always create accentuated modification in the two factors studied.

Meanwhile, what seems perfectly logical is the different sensitivities of
**CONCLUSIONS**

Completing the discussions of all aspects raised, the following conclusions could be inferred.

- the aerial part of sugarcane experienced more significant increase with the liming than the radicular system did;
- the chemical composition of the soil suffered sensible variations in what is said in respect to the contents of Al^+3, Ca and Mg correlated better with the liming than with the production of dry material in the aerial parts;
- sugarcane showed itself sufficiently tolerant of the content of exchangeable Al in the soil. The treatment with Al^+3 = 1.0 meq did not differ...
FIGURE 4. Relation between \( \text{Ca(OH)}_2 \) added and index of saturation of the bases (V%) of the soil.

from the treatment with \( \text{Al}^{3+} = 0 \text{ meq} \);

- the need of limestone (NC), could be obtained from the results of the product of the exchangeable Al in the soil times 1.5 (NC = meq \( \text{Al}^{3+} \times 1.5 \)).

REFERENCES


EFECTO DE ENCALAR EN LA PRODUCCIÓN DE CANA DE AZÚCAR Y EN LA FERTILIDAD DEL SUELO EN EL ESTADO DE PERNAMBUCO

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Antonio Pinto Medeiros y José Maria de A. Pereira

RESUMEN

Un experimento utilizando un suelo latosol rojo-amarillento de la zona cañera de Pernambuco Meridional se llevó a cabo en tiestos, con el objetivo de determinar los efectos en la materia seca de la caña de azúcar y la fertilidad del suelo con niveles de encalamiento correspondientes a 3.56 (Al = 0 meq); 1.40 (Al = 0.5 meq); 1.04 (Al = 1.0 meq) y 0.64 (Al = 1.5 meq) t/ha de Ca(OH)2.

Se confirmó el efecto de encalar sobre la producción de materia seca de las partes aéreas de la caña. No se detectó significancia estadística en las raíces a pesar de reducir el nivel de encalamiento.

Los diferentes niveles de Ca(OH)2 decididamente influyeron en la absorción de Ca y Mg en las partes aéreas de la caña.

El encalado aumentó los contenidos de Ca y Mg y la saturación de los bases y redujo los contenidos de Al y H del suelo. Exceptuando al P, los valores extremos se obtuvieron con 3.56 t/ha de Ca(OH)2.

Las correlaciones entre Al3+ en el suelo fueron significativas a 1% de probabilidad y presentaron coeficientes de correlación lineales positivas para meq (Ca2+ + Mg2+) y negativas para meq Al3+, sin embargo ambas fueron iguales en cuanto a valor absoluto.