STUDIES IN THE PHYSICAL AND CHEMICAL PROPERTIES OF SOME SUGARCANE SOILS.

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Although it is not easy to find the cause which accounts for the fact, it is well known that the growth of sugarcane in many places becomes poorer year after year. Though the cultivation operations improve the physical condition of the soil and increase the availability of plant nutrients, there is a limit however to the benefit which can thus be obtained. In the middle of the last century, Reynoso¹ working on certain sugarcane soils, finds that the most robust canes are grown in calcareous soils and that these also afford juices rich in sugar. From that time many investigators have worked on this problem. Notable among these being Harrison² working on British Guinea soils, Crawley³ on Cuban soils and Burgess and Kelley⁴ on Hawaiian soils. But none of these workers seem to have tried to co-ordinate and find out the cause of this deterioration of the soils and of the presence of poorly grown canes. Isaburo Wado and Sunao Ato⁵ tried to co-ordinate the results of analysis of some of the robust and poorly grown canes and some of the "fertile" and "infertile" soils supplied to them by the Ensuike Sugar Manufacturing Co., but their results do not seem to be conclusive.

The chemical changes that proceed in a well-cultivated soil are essentially of the nature of oxidation. Hence it appears quite possible that if the changes can be accelerated by certain chemical treatments, better plant growth and greater increase in yield may be expected. During recent years there has been an increasing evidence to show that many of the elements which have been hitherto regarded as "unessential", exercise marked influence on the plant growth. Subramanyan and collaborators⁶ have shown in a series of papers that the organic matter either belonging to the soil or that which is added as manure undergoes decomposition yielding mineral nutrients in available form. They have also shown that the decomposition which is rather slow under natural conditions can be considerably hastened by the addition of mild oxidising agents resulting in the larger release of plant nutrients and larger yield of crop.

According to Leibig⁷ the productivity of a soil is not however so much governed by the combined effect of all controlling factors as by the influence
of one decisive feature. These trace elements may effect the availability of soil nutrient reserves or when applied with ordinary chemical fertilisers may increase their effect—even rendering them of benefit where they normally fail. Among the various workers who have contributed to this line of research mention must be made of Bertrand and co-workers,\textsuperscript{9} Warrington,\textsuperscript{9} Somer and Hass\textsuperscript{10} and Reid who have shown that minute quantities of F, I, Zn, Al, Mn and B are essential to the normal growth of plant. The great importance of traces of Mn for the plant has been demonstrated by McHargue, McLean, Kelley and Gerrestsen.\textsuperscript{11} Kelley while studying the Hawaiian soils, observed the presence of large quantities of Mn and Ti while Gerrestsen believes that Mn intensifies photosynthesis by accelerating the oxidation processes connected with the photochemical reactions in the leaf, shortage of Mn resulting in a retarded carbon dioxide assimilation. The occurrence of Mo and V in nature has been well studied by Mueken,\textsuperscript{12} Dingwall,\textsuperscript{13} Horner\textsuperscript{14} and others. These investigators have observed that applications of Mo will increase at times the growth of azotobacter cultures two- or three-fold.

Recently, Dhar and his collaborators\textsuperscript{15} investigating the application of molasses to the soil and the consequent photonitrification, observe that in tropical soils the fixation of atmospheric nitrogen by the addition of energy-rich compounds is photochemical and catalytic, and that compounds of Mn, Zn and traces of Ti greatly facilitate the oxidation reactions occurring in the soil.

In connection with his recent experiments on the utilisation of molasses as fertiliser, the author had occasion to investigate the physical and chemical characteristics of some typical soils from cane-growing areas. It is proposed here to give the results of the investigation which mainly deal with fertile and infertile samples from the same locality. After years of cultivation and manurnal treatment it was found that in the same locality some soils were unproductive for sugarcane cultivation while the others responded well to manural treatments, as indicated by the return in the quantity as well as the quality of the cane. On this basis the soils (0·1' depth) were kindly supplied to the author by Mr. S. S. Patrudu, Superintendent of the Agricultural Research Station, Anakapalli, as representing "fertile" and "infertile" fields in adjacent blocks.

Physical Studies.—The soil-water relationships are largely dependent upon the textural composition of the soil. The mechanical composition as a method of expressing the texture of soils has been generally recognised. But in the ordinary methods the dispersion effected seems to be inadequate to separate the soil colloids from the mineral particles.
Samples from a fertile and infertile zone are analysed for a number of physical properties, including a study of the spectra emitted under suitable conditions by these soils. The samples (from the fertile and infertile regions obtained from a sugarcane field near Vizagapatam) contained the following main fractions:

- Clay (0·002 mm. & below) 15·12 %
- Silt (0·02 to 0·002 mm.) 6·15 %
- F. Sand (0·2 to 0·02 mm.) 44·12 %
- C. Sand (2·0 mm. to 0·2 mm.) 33·10 %

These soils occupy a large proportion of the cultivated and uncultivated areas of the tract. The absorptive capacities of the soils were next studied in squat form weighing bottles. About 10 gm. of the sample is taken in the weighing bottle and exposed to sulphuric acid-water mixtures in vacuum desiccators, which were kept in a thermostat at 30° C. Constancy of weight was attained after a period of forty-eight hours. But they are usually exposed for not less than three days and the moisture content determined in a hot-air oven at 105° C. The results obtained for duplicate samples from the fertile and infertile regions are given below for the relative humidities at which the experiment was done.

**Table I.**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rel. Hum. 20%</th>
<th>40%</th>
<th>60%</th>
<th>80%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertile 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2·43</td>
<td>4·04</td>
<td>5·73</td>
<td>7·04</td>
<td>9·98</td>
</tr>
<tr>
<td>2</td>
<td>2·31</td>
<td>4·06</td>
<td>5·86</td>
<td>7·05</td>
<td>10·12</td>
</tr>
<tr>
<td>Infertile 1</td>
<td>0·52</td>
<td>1·63</td>
<td>2·21</td>
<td>3·04</td>
<td>5·13</td>
</tr>
<tr>
<td>2</td>
<td>0·56</td>
<td>1·68</td>
<td>2·27</td>
<td>3·00</td>
<td>5·18</td>
</tr>
</tbody>
</table>

(For the hygroscopic moisture at 100% R.H. water was used in the desiccator instead of sulphuric acid.)

It is interesting to note that though the mechanical composition of the soils was practically the same for the two fields yet the powers of absorption of water varied considerably and it is here that we can seek for an explanation for the difference in fertility of the two fields.

The absorption of water vapour by the soils when exposed to sulphuric acid of 3·3 per cent. strength at 28°·5 C. giving a relative humidity of
98 per cent. was studied over a period of 50 days in order to see whether these differences in the absorptive capacities persist. The results of this experiment are given in Table II below:

**Table II.**

*Moisture Content at Different Periods.*

<table>
<thead>
<tr>
<th>Time in days</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>4.2</td>
<td>9.1</td>
<td>10.5</td>
<td>11.4</td>
<td>12.0</td>
<td>12.1</td>
<td>12.1</td>
<td>12.2</td>
<td>12.2</td>
<td>12.2</td>
<td>12.2</td>
</tr>
<tr>
<td>Sample 2</td>
<td>1.4</td>
<td>4.2</td>
<td>5.3</td>
<td>6.2</td>
<td>6.4</td>
<td>6.5</td>
<td>6.6</td>
<td>6.6</td>
<td>6.6</td>
<td>6.6</td>
<td>6.6</td>
</tr>
</tbody>
</table>

Sample 1 is from a fertile field and the sample 2 is from the infertile area. Duplicates agreed well; hence a mean value only is given above.

The absorption is very rapid at first and then the rate diminishes. The rate of absorption follows an exponential relationship with time of the type

\[ R = k (1 - ae^{-kt}). \]

The equation when applied to the absorption of moisture by the soil samples given above becomes

\[ R = 12.2 \times (1 - 0.65 \times 10^{-0.06t}) \] for sample 1
\[ R = 6.7 \times (1 - 0.79 \times 10^{-0.07t}) \] for sample 2, where

\( R \) is the moisture content in time \( t \) days.

It is clear from the above that the higher absorptive capacities displayed by the samples from the fertile field might be due to the presence of higher amount of colloidal in these samples.17

A determination of the colloidal matter present in the soil samples was made using the method due to G. J. Bouyoucos18 known commonly as the hydrometer method. The duplicate samples from the two fields gave the following values at the laboratory temperature.

- Fertile (Sample 1) 21.12% colloids
  (Sample 2) 20.03% ,,  
- Infertile (Sample 1) 12.21% ,,  
  (Sample 2) 10.13% ,,  

The above values confirm the observations made earlier that the differences in the absorptive capacities might be due to the different amounts of colloids present in the samples.

The Chemical Analysis of the above samples was done by the methods of the A.O.A.C. It is surprising to note that with the exception of Lime the major constituents did not vary in the two blocks.
## Physical and Chemical Properties of Some Sugarcane Soils

<table>
<thead>
<tr>
<th></th>
<th>Fertile block</th>
<th>Infertile block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insolubles</td>
<td>74.12</td>
<td>83.17</td>
</tr>
<tr>
<td>Iron and Alumina</td>
<td>6.73</td>
<td>7.42</td>
</tr>
<tr>
<td>Lime as CaO</td>
<td>12.10</td>
<td>6.52</td>
</tr>
<tr>
<td>MgO</td>
<td>1.52</td>
<td>1.56</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.21</td>
<td>0.27</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.64</td>
<td>0.55</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.09</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Organic carbon and total nitrogen in the samples was found to be as follows:

<table>
<thead>
<tr>
<th></th>
<th>Fertile</th>
<th>Infertile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Carbon</td>
<td>1.20</td>
<td>1.05</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>0.0475</td>
<td>0.0398</td>
</tr>
</tbody>
</table>

The above values do not conclusively show any great differences in the major constituents of the soils including the total nitrogen and organic carbon, for the fertile and infertile blocks, at least as much as to be able to account for the observed differences in the absorption towards water. The experiments conducted by the author show beyond doubt that these differences in the powers of absorption are due to the differences in the colloidal content. In this connection attention may be drawn to the views of F. J. Alwaye, P. L. Gilc and their co-workers. "The colloidal material of the soils", according to Emil Troug, "is usually largely mineral and rarely is 10 per cent. or more of it organic".

For reasons stated above a search for the mineral constituents including the trace elements was made. The work reported here is of a preliminary nature, as far as the section on the spectrographic analysis is concerned, which was mainly undertaken with a view to standardise the technique employed in the analysis of soils. Concentrations of the trace elements are usually so minute that their detection and estimation would require
profound study of methods followed by laborious research in large quantities of the material.

Spectrographic investigations of trace elements avoid these difficulties and the process of obtaining an ultimate mineral analysis of a soil becomes very simple. The spectrograph can present successive stages of a profile on a single plate revealing at a glance variations in the quantity of an element. A comparison of the intensities of the lines in the various spectra leads to fairly reliable results. The author has therefore photographed the arc spectra of the soil samples and this preliminary investigation is mainly intended to finding all the metallic elements contained in the soils without allowing even the rare ones to escape detection. For this purpose, soils previously prepared according to the official method and reduced to fine powder were used in a carbon arc, using for the purpose hollowed out carbon electrodes filled with the samples and a direct current of five amperes. A slightly different form of carbon arc which was found to be specially serviceable in obtaining the spectra of metals having low boiling points was used. In this the upper carbon is surrounded with a water-box through which there is kept a constant flow of cold water which prevented the temperature of the electrode from becoming too high. The spectra were photographed with a Hilger quartz spectrograph and standard spectra were impressed on each plate using for the purpose samples made for pure metals and chlorides of metals. The carbon electrodes used in these experiments were of the H.S. brand purity supplied by Adam Hilger. In all cases they were mounted vertically and were brought together with a gap of about 2 mm. and the arc was struck by drawing a third carbon electrode of the same kind across the gap and the current was maintained constant for all the exposures.

The spectra are reproduced in Plate XI in which 'A' is the spectrum obtained with the mixture containing Na, K, Ca, Mg, Cu, Fe, Si, Al, and Ti, Mn, Zn, V in suitable ratio. 'B' and 'C' are spectra of fertile soils and 'D' and 'E' for the infertile samples for the same locality. The minerals which could be indubitably detected and identified from these are Na, K, Cu, Mg, Ca, Al, Si, and Fe and the trace elements Zn, Ti, Mn and B while the presence of Be is suspected. By comparing the spectra of these soil samples with those of a series of suitable ratio powders of known composition attempts have been made to determine the proportion of the minor constituents. By this method, the Mn content of the majority of the fertile soils was found to range from 0.04 to 0.15 while the value of Zn ranged from 0.03 to 0.06. While the problem is evidently more complicated than would at first sight appear, there seems to be nonetheless a connection between Zn, Mn and Ti content and fertility.
Valuable information might be obtained by the spectroscopic examination of soils and the ashes, roots and stems and leaves of plants that grow in these soils supplemented by the chemical estimation of the trace elements. Further experiments in this direction are in progress and the author proposes to deal with these in another communication.

Summary.

A detailed study of the physical and chemical properties of some fertile and infertile soils from sugarcane-growing areas has been carried out. The study involves the determination of the colloid content, chemical composition and spectroscopic examination for the minor constituents. Although there has been no significant difference in soil composition, attention is drawn to the role of trace elements Zn and Ti in plant nutrition. Arc spectra of these soil samples have been photographed and by comparing these spectra with those of a series of suitable ratio powders of known composition attempts are made to determine the proportion of the trace elements.

REFERENCES.

1. Noel Deer, *Cane Sugar*, 1921, p. 68.
2. Ibid., 1921, p. 70.
3. Esterian Central Agronomica, Cuba, Boletin, 28.
11. Trans. 3rd Int. Congress of Soil Science, 1, 189-91.