

# SOME PHASES OF SOIL INVESTIGATION RELATING TO WORK AT THE EXPERIMENT STATION

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The aim of soil analysis from the agricultural chemist's point of view is to provide a means of judging the fertility of the soil. Owing to the complex nature of the soil and furthermore the complex mechanism underlying the absorption of mineral elements, the whole problem is still on a very uncertain basis. Each year it is noticed how the outlook in soil science is broadened, and our chemical knowledge of the "dynamic system" (as Prof. de'Sigmond calls the soil), is continually being modified. Owing to limited means, however, the Experiment Station cannot hope to examine or put into effect many of the newer discoveries relating to soil research, and consequently in soil analytical work we have thought it wiser in the interim not to depart too hastily from the more classical methods of investigation.

The field is wide, and as pointed out above complex, and there are very many ways of tackling the problem of soil fertility, of ascertaining whether a soil is capable of producing good crops or not. But from whatever angle we approach, it has to be remarked that it is the plant and the plant only which can give us a practical indication of soil fertility. Hence the great importance which attaches to further studies in plant physiology.

Before proceeding to discuss some of the phases of soil study conducted at the Experiment Station, mention may be made of an extensive problem which still faces us, namely that of surveying the soils of the sugar belt. The soil survey work of the Javan sugar industry under the direction of Arrhenius, has been based on pH, phosphate content, and the nitrifying power of the soil. This intensely practical, and apparently efficient system of soil survey, soon attracted the attention of the Philippine Sugar Industry<sup>1</sup> which was at that time somewhat backward in soil research. Later, however, we note a reaction against Arrhenius' "meteoric irruption," and a few years ago the Javan Station considered that his method did not constitute a real soil survey.

A "genetic method" was proposed in which soil colour and texture were the distinguishing characteristics. In other words, it was a getting back to soil types though still to be criticised as being insufficiently general. Rutten<sup>2</sup> concludes that no future soil survey should be made on other than genetic principles and based on the geology of the sub-soil. It seems then that any attempt at soil survey work should be based on very careful thought and in the light of experience gained by other sugar growing countries.

Soil investigational work, however, continues to play an important rôle in the duties of the Experiment Station. Soils are studied with regard to their physical and chemical composition. The physical analyses relate to the study of certain moisture relationships and to the grading of the soil into its fractions. The chemical analyses relate to (1) the available plant foods (2) the total reserves, and (3) the miscellaneous constituents and reactions.

Methods have been proposed from time to time for estimating "readily available," "moderately available" and "slowly available" plant foods, but such methods can only be looked upon as very empirical. The well established citric acid method for available plant foods can at this stage only be accepted, and the hydrochloric acid extraction method retained when it is desired to know the total richness of the soil. Much aspersion has recently been cast upon this latter process and has ultimately led to its total disuse by many soil institutions. Considerable work, however, has been done here using the hydrochloric acid extraction method and on the basis of our experience we have to record that this study, while admitting of many exceptions, has often proved highly instructive. The writer has shown in a preliminary study of this method<sup>3</sup> that it does indicate in some degree the fertility of the soil. The necessity of co-ordinating such figures with a study of field conditions was also indicated.

The rapid methods of ascertaining "nutrient deficiencies or chemical abnormalities of soils" which have recently come into vogue in Hawaii and America<sup>4, 5</sup>, are being noted, though for all routine work the citric acid method is still retained. Many alternative solvents exist in the literature and are one and all based on the still very uncertain hypothesis that plant roots excrete a weak acid which attacks the compounds of the soil.

Recently Malherbe and Myburgh<sup>6</sup> made an examination of ten well known methods for determining available phosphate in soils and came to the conclusion that the Standard Dyer method (using 1 per cent. citric acid) was the most satisfactory. Though this method is used by the Experiment Station, the writer has had occasion to indicate<sup>7</sup> that citric soluble figures are by no means an infallible guide to field conditions.

Apart from work on replaceable bases it is not intended to discuss the miscellaneous estimations

which are made on soils. In the appended table is shown an analysis of eight typical soils.

Since the study of the replaceable bases in the soil is assuming a prominent part in soil investigational work in other countries, it is thought that a short review of this work would not be out of place.

Hitherto no great amount of work has been done here on this subject and in consequence no conclusions can be arrived at. Nevertheless a study of the base exchange property of the soil has been considered of importance by most writers on this subject. Most of the food material of plants is believed to reside in the exchange complex of the soil. Thus Tyner points out<sup>8</sup> that in many soils almost all the readily available potassium exists in the exchangeable form, and Lamb<sup>9</sup> found potassium starvation to be associated with low exchangeable potassium and high exchangeable calcium. Furthermore experience seems to have shown that a good soil contains a large amount of replaceable bases. The numerous methods used from time to time in determining replaceable bases may be divided into (a) digestion and leaching methods with a neutral salt solution or a weak acid solution such as acetic acid or even hydrochloric acid<sup>10</sup> (b) the separation of the replaceable bases by electro dialysis<sup>11, 12, 13</sup>. Amongst the extracting or leaching solutions which have been recommended from time to time may be mentioned Schollenberger's neutral solution of ammonium acetate<sup>14</sup>, recommended further by Merkle<sup>15</sup>; Williams' semi-normal solution of acetic acid<sup>16</sup>, later applied by him to carbonate soils<sup>17</sup>; the cold ammonium chloride extractions made by Kelley, Brown, Melvin<sup>18</sup> and others; the recent method of Puri<sup>19, 20</sup> employing ammonium carbonate solutions for non-calcareous soils, followed by treatment with potassium chloride in the case of calcareous soils. Specially worked out for calcareous soils may be mentioned Hissink's method using normal sodium chloride solution<sup>21</sup>, employed further by Salgado<sup>22</sup>; boiling ammonium chloride solution as used by Shaw and MacIntire<sup>23</sup>; and Burgess and Breazeales' solution of barium chloride<sup>24</sup>. The method of Williams, referred to above<sup>17</sup>, being simple and applicable to both calcareous and non-calcareous soils, is very suitable, though as Puri has pointed out<sup>25</sup>, acetic acid, owing to its low ionization constant, is unsuitable for this work.

The writer has recently attempted to extend the study of base exchange phenomena by leaching and digesting soils with a solution containing a mixture of acetic acid and sodium acetate at pH 4.75, the acid reaction found in cane roots.

Insufficient work has been done so far to report on this work, though it is observed with interest that a similar attempt has recently been made by Morgan<sup>26</sup> buffering his "Universal" soil extracting solution to pH 4.8.

Before concluding this brief discussion, reference must be made to the advisability or otherwise of determining substances other than the more common plant foods phosphoric acid, potassium, and calcium. The literature abounds with references to the value of the less common elements in plant nutrition, and Lundegårdh<sup>27</sup> has gone as far as to show that certain metallic ions such as copper, cobalt, lead, thallium and mercury have a remarkable effect on the cell mechanism of the plant. Amongst such substances the determination of iron, aluminium, manganese, magnesium and silica can be recommended in routine analysis. To determine quantitatively lesser known elements is not only tedious but can have very little meaning, as the quantities required by plants are so small. Elements such as boron and sulphur are required only in minute quantities, and only in cases where plant poisoning is suspected would it be necessary to extend the study to include such elements.

An effective supplement to soil investigational work is to determine the elements in the material of the plants grown on the fields. Thus Moir<sup>28</sup> points out that analysis of cane juice for phosphoric acid and potash have afforded valuable aids in fertilization problems. Such determinations have been made with sugar canes analysed here, and from the variation of the content of these substances with different fields of cane it appears that interesting correlations can eventually be deduced.

This paper is not an attempt to summarise the numerous lines of investigation open in a study of the soil. Such lines are too numerous and much soil investigational work is at present barely out of the tentative stage. What is eminently required of an institution such as this is a specialisation in those problems which have a practical relation to the fertility of the soil. A complete understanding of the soil is not an easy matter. Problems which at first appear simple can become very complex. One problem leads to another and frequently the characterising feature of a soil arises from more than one cause. Nor are all these questions of chemical composition, but also of physical texture, of drainage, and of moisture content. In our study of the soil, therefore, the necessity for making a close study of the soil in situ must not be overlooked. Soil analytical work has been most criticised on the grounds that the agricultural chemist works in the laboratory with small samples which do not reflect the true state of the soil. But if the agricultural chemist takes into consideration the local conditions of the particular soil in hand and combines this information with that gained from his analytical work, there seems no reason why such work cannot eventually throw light on the peculiar characteristics of certain soil types, and enable us to afford practical advice to planters on the more obscure soil problems.

**TABLE OF ANALYSIS OF SOME TYPICAL SOILS.**

**A.—Chemical Analysis.**

(1).—Digestion of soil for 10 hours over water bath in HCl. (1.115 S.G.)

Soil Sample.	E1. N/S	C7. P.E.A.	N.E.—N2.	L.	E2.	F1.	P1.	N.E.—A3.	M.
Insoluble Residue	81.29	62.69	94.98	95.75	71.17	85.50	55.87	84.76	94.51
Soluble Silica (S.O <sub>2</sub> )	0.92	0.10	0.20	0.05	0.96	0.20	0.59	0.57	0.04
Loss on Ignition	5.70	12.67	1.30	1.07	8.32	4.83	15.58	5.42	2.23
Potash (K <sub>2</sub> O)	0.10	0.25	0.03	0.04	0.08	0.09	0.36	0.10	0.04
Phosphoric Acid (P <sub>2</sub> O <sub>5</sub> )	0.01	0.13	0.04	0.05	0.02	0.04	0.10	0.02	0.06
Lime (CaO)	0.28	0.52	0.13	0.05	0.19	0.17	0.83	1.32	0.08
Magnesia (MgO)	0.20	0.74	0.06	0.04	0.10	0.11	0.24	0.13	0.06
Manganese (MnO)	—	0.10	—	—	0.10	—	—	—	0.04
Titanium (TiO <sub>2</sub> )	—	0.22	—	—	0.28	—	—	—	0.06
Alumina (Al <sub>2</sub> O <sub>3</sub> )	4.00	13.03	0.88	0.86	8.35	1.41	13.54	1.52	0.69
Iron (Fe <sub>2</sub> O <sub>3</sub> )	7.58	9.05	2.45	2.17	10.14	7.94	13.17	6.11	2.09
Not determined	—	0.50	—	—	0.29	—	—	0.05	0.10
<b>Total</b>	<b>100.08</b>	<b>100.00</b>	<b>100.07</b>	<b>100.08</b>	<b>100.00</b>	<b>100.29</b>	<b>100.28</b>	<b>100.00</b>	<b>100.00</b>

(2).—Miscellaneous.

Total Carbon	1.58	2.61	0.71	0.68	2.16	1.58	4.60	1.46	1.08
Total Nitrogen	0.12	0.19	0.04	0.07	0.27	0.12	0.31	0.11	0.10
Carbon: Nitrogen ratio	13.1	13.7	17.7	9.7	8.0	13.2	14.8	13.3	10.8
Available Potash (K <sub>2</sub> O)	0.012	0.013	0.013	0.002	0.010	0.004	0.030	0.015	0.006
Available Phosphoric Acid (P <sub>2</sub> O <sub>5</sub> )	0.001	0.013	0.003	0.005	0.002	0.002	0.008	0.010	0.004
pH Value	6.30	6.41	7.22	6.62	6.23	5.34	6.53	8.40	5.45
Lime Requirement (Tons CaCO <sub>3</sub> p.a.)	1.02	—	—	0.44	—	—	2.66	—	—
Moisture at 50% R.H.	—	—	0.08	—	—	—	—	0.54	—
Organic matter	2.64	3.47	0.59	—	—	—	—	3.32	0.96
Moisture at 105° C.	4.52	5.83	0.39	0.31	4.17	1.75	8.94	2.57	0.60

(3).—Clay fraction (by fusion).

Silica (SiO <sub>2</sub> )	47.68	—	68.40	—	—	—	—	53.48	61.72
Iron (Fe <sub>2</sub> O <sub>3</sub> )	20.48	—	11.80	—	—	—	—	17.28	9.20
Alumina (Al <sub>2</sub> O <sub>3</sub> )	23.36	—	16.36	—	—	—	—	27.36	23.44
SiO <sub>2</sub> /Al <sub>2</sub> O <sub>3</sub> ratio	3.47	—	7.10	—	—	—	—	3.32	8.26
SiO <sub>2</sub> /R <sub>2</sub> O <sub>3</sub> ratio	2.22	—	4.86	—	—	—	—	2.60	4.48

**B.—Physical Analysis.**

Coarse Sand	18.40	0.62	68.05	76.08	12.64	18.96	—	17.68	67.82
Fine Sand	40.20	9.01	20.71	12.25	34.01	47.82	—	46.28	15.80
Silt	12.35	33.15	3.70	5.80	13.85	10.45	—	13.60	7.60
Clay	20.40	42.10	4.45	0.95	31.75	18.20	—	16.75	6.15
Moisture	4.52	5.83	0.39	0.31	4.17	1.75	—	2.57	0.60
Carbonates	—	—	—	—	—	—	—	—	—
Loss by Solution (Fe <sub>2</sub> O <sub>3</sub> etc.)	0.84	1.21	0.37	1.15	1.09	0.62	—	2.44	0.31
Diff. (Organic matter, etc.)	3.29	8.08	2.33	3.46	2.49	2.20	—	0.68	1.72
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>—</b>	<b>100</b>	<b>100</b>

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The CHAIRMAN: Before going on to the discussion of this very suggestive paper by Mr. Beater. I suggest that we ask Mr. Cutler to speak to us. and then we can deal with both papers together, because they cover more or less the same subjects from different points of view.

Mr. CUTLER: I might say with regard to this paper, I had no idea when I wrote it that it would be copied and put before you. I have been in contact with the Sugar Experiment Station for some time past, and we have given such assistance as lay in our power; and in view of a certain amount of general reading and investigation which has been carried out up there, I thought I would put before you some ideas in regard to the trend of soil science as they struck me personally. The paper is simply a collection of personal thoughts strung together with regard to the various phases of soil study, and you must please take them as such, with the idea of calling your attention to particular lines of approach in soil problems. One can only indicate the general lines of approach applicable to local conditions. I propose to read this paper in part, and break away now and again and give a little explanation, and perhaps cut a little. It is rather a long paper and I do not want to take up too much of your time.