NOTE ON THE ABSORPTION OF PLANT-FOODS BY SUGAR CANE

By E. P. HEDLEY, Ph.D., and B. E. BEATER.

The following paper was read by Dr. E. P. Hedley:—

It is well known that a crop with such vigorous growing powers as sugar cane must necessarily remove large quantities of plant-food from the soil. In order to determine approximately the total requirements of the growing plant and to come to appreciate more fully its demands upon the soil, the authors undertook to analyse a number of stools of cane from various localities.

The samples were designated as follows:—

Uba A.—2 years old, first ratoon, 23 sticks in stool, average length of stick 6 feet 6 inches. Total weight of stick and tops 57·5 lbs.

Uba B.—21 months old, first ratoon, 20 sticks in stool, average length of stick 7 feet. Total wieght of stick and tops 36·3 lbs.

Uba C.—2 years old, plant cane, 16 sticks in stool, average length of stick 5 feet. Total weight of stick and tops 23 lbs.

Uba D.—2 years old, first ratoon, 16 sticks in stool, average length of stick 4 feet 6 inches. Total weight of stick and tops 20·8 lbs.

Co. 290.—21 months old, plant cane, 7 sticks in stool, average length of stick 6 feet. Total weight of stick and tops 17·4 lbs.

Co. 281.—21 months old, plant cane, 12 sticks in stool, average length of stick 7 feet. Total weight of stick and tops 34·5 lbs.

The stool, which was chosen at random, was removed as completely as possible from the soil, and upon arrival at the laboratory was divided into the following three sections:—

1. Green leaves and trash.
2. Stems, from ground level to first green leaf.
3. Roots, including buried portions of cane stalk.

In the course of analysis each portion was treated separately.

The whole of each part of the plant was comminuted separately, and the resulting pile thoroughly mixed and sub-sampled. The samples were carefully dried in an electric drying oven to determine the moisture content, and after drying they were burnt to obtain the ash for the analyses. Each analysis was done in duplicate on separate samples, so as to be certain that a representative sample had been taken. In all cases the agreement was good.

Total nitrogen was estimated by the usual kjeldahl method, taking for analysis 2 to 3 grammes of the dried material. Phosphoric acid, potash, calcium and magnesium were estimated on 10 grammes of ignited material.

In the following table the analytical results are reported as percentages of the *dry substance*.

TABLE I.—**Leaves and Tops.**

	Uba A.	Uba B.	Uba C.	Uba D.	Co.290.	Co.281.
	%	%	%	%	%	%
N_2 ..	0·670	0·500	0·460	0·480	0·444	0·477
P_2O_5 ..	0·195	0·155	0·192	0·140	0·129	0·153
K_2O ..	2·550	0·884	1·014	1·675	0·950	1·187
CaO ..	0·367	0·497	0·523	0·366	0·444	0·380
MgO ..	0·356	0·636	0·212	0·234	0·499	0·341

TABLE II.—**Stems.**

	Uba A.	Uba B.	Uba C.	Uba D.	Co.290.	Co.281.
	%	%	%	%	%	%
N_2 ..	0·280	0·250	0·200	0·327	0·240	0·158
P_2O_5 ..	0·098	0·077	0·111	0·183	0·061	0·148
K_2O ..	1·662	0·487	0·812	1·387	0·642	0·971
CaO ..	0·065	0·079	0·113	0·036	0·086	0·075
MgO ..	0·081	0·195	0·030	0·144	0·421	0·141

TABLE III.—**Roots.**

	Uba A.	Uba B.	Uba C.	Uba D.	Co.290.	Co.281.
	%	%	%	%	%	%
N_2 ..	0·560	—	—	0·627	0·348	0·340
P_2O_5 ..	0·150	—	—	0·162	0·102	0·163
K_2O ..	0·881	—	—	0·842	0·675	0·625
CaO ..	0·088	—	—	0·103	0·082	0·129
MgO ..	0·068	—	—	0·122	0·136	0·075

Table IV. represents the amount of plant-food in pounds actually taken up by the plant. Since no roots were obtained with Uba B and C, the figures for these samples represent the amount taken up by stems, leaves, and tops alone.

TABLE IV.

	30-TON CROP.				40-TON CROP.	
	Uba A.	Uba D.	Uba B.	Uba C.	Co.290.	Co.281.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
N_2 ..	391	420	223	183	336	382
P_2O_5 ..	112	130	70	82	95	164
K_2O ..	1,195	1,044	402	467	724	1,018
CaO ..	133	154	193	188	234	245
MgO ..	126	139	263	74	343	224

In order to determine how much plant-food was actually removed from the field by the stems, the following table (V.) was drawn up and represents the analyses of the stems, as they are sent to the factory. The figures supplied by this table should be of interest to the planter, who is apt to overlook the heavy toll the cane takes of the plant-food reserves of his fields and is not returned.

TABLE V.

	30-TON CROP.				40 TON CROP.	
	Uba A.	Uba B.	Uba C.	Uba D.	Co.290.	Co.281.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
N_2 ..	44	42	34	56	51	38
P_2O_5 ..	15	13	19	31	13	36
K_2O ..	259	82	139	237	137	237
CaO ..	10	13	19	6	18	18
MgO ..	13	33	5	25	90	34

NOTE.—To convert the figures in Tables IV. and V. into their equivalent in fertilizers, multiply the nitrogen by 10 to get whale guano, by 5 for ammonium sulphate, and 6.2 for sodium nitrate. For superphosphate multiply P_2O_5 figures by 5.9, and K_2O by 1.66 to get the equivalent in muriate of potash.

The figures also serve to illustrate how greatly the mineral content varies. It is questionable, on the other hand, whether the crop does require all the plant-foods which it absorbs. With the exceptiona of Uba A, these samples of cane did not appear to vary much one from another, and yet there is a considerable difference to be observed in the pounds of potash removed by two very similar canes, as, for example, Uba C and Uba D. Such wide variations are also observed in the analyses for other plant-foods, and prove that no definite conclusions can be drawn from such analyses, even though the samples may be chosen with the greatest care.

It must be noted, however, that these analyses were made in July. Were they made in December or thereabouts, the pounds "phosphoric acid" would undoubtedly be very much higher. The same, indeed, may be said of the other elements.

These observations are supported by Dr. Boname's remarks in the annual report of the Agricultural Station of Mauritius (Bulletin No. 26, 1912, p. 928). He says:—

"The composition of the cane is modified during vegetative processes, both with regard to its sucrose content as well as the nature and proportion of the mineral elements removed from the soil."

The statement is supported by many analyses which go to prove the interesting manner in which the mineral matter varies. In conclusion, however, since all the mineral matter does vary, these analyses may be accepted as a time indication of the proportion of mineral elements present at a particular period of growth.

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CHAIRMAN: This is not a very long paper, but there is a tremendous amount of information in it. I came across an interesting point the other day in a paper read by Moir of Hawaii, in which he states that a good growth of cane requires 120 lb. of P_2O_5 and 1,200 lb. of potash, that is for twelve inches of soil per acre. So with increasing crops we may expect considerably more than the figures shown here. I am very pleased to be able to tell you that we have with us to-day Mr. Lintner, who, I understand, has some corroborating data on this paper, and I would ask him to give us his data now.

Mr. LINTNER: the paper which has just been read, by Dr. Hedley and Mr. Beater, is the most interesting one we have had for a very long time.

This paper compiles probably the first figures of this nature obtained from such analysis in this country. The most interesting point perhaps to be noticed in the figures themselves, is the relationship between the nitrogent content of leaves and tops, stems and roots as compared with potash.

It appears to establish the same thing that has been found elsewhere, that these two elements go hand in hand in plant physiology. Nitrogen, as you will remember, is responsible for the general growth and abundant and luxuriant leaf growth. Potash is associated with the efficiency of unit area of leaf in the assimilation of carbon dioxide and with the translocation of synthesised carbohydrates from the leaves to the places of storage. The figures in Dr. Hedley's paper are most encouraging for further work in the field, provided enough attention is paid to other factors, especially the soil. In the fifth paragraph from the end, the authors appear to have lost confidence in the figures obtained on account of the variation in different specimens. I personally do not attach any importance to this variation, beyond the fact that such differences are probably due to pedological variations.

There is no doubt that soil analysis alone as a factor for deciding the soil's requirements in fertiliser, is inadequate, beyond being a valuable method of control

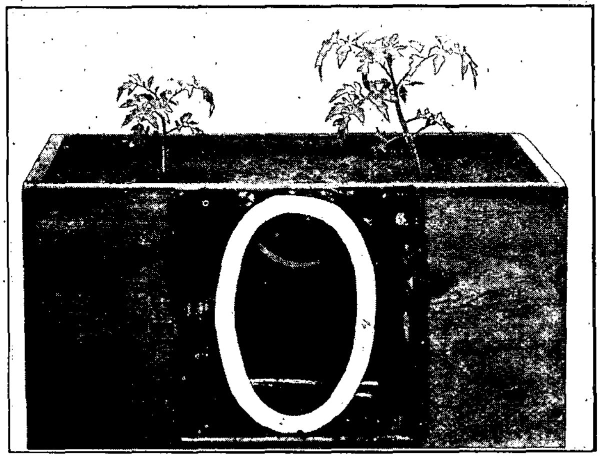

FIG. 1

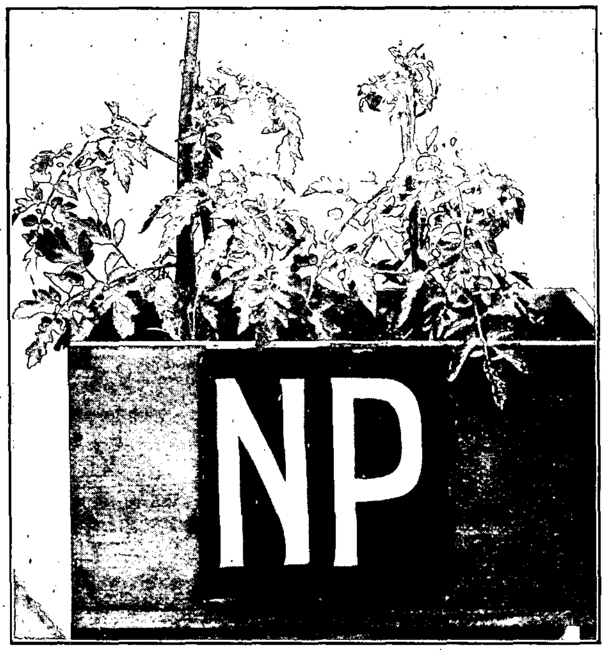

FIG. 2.

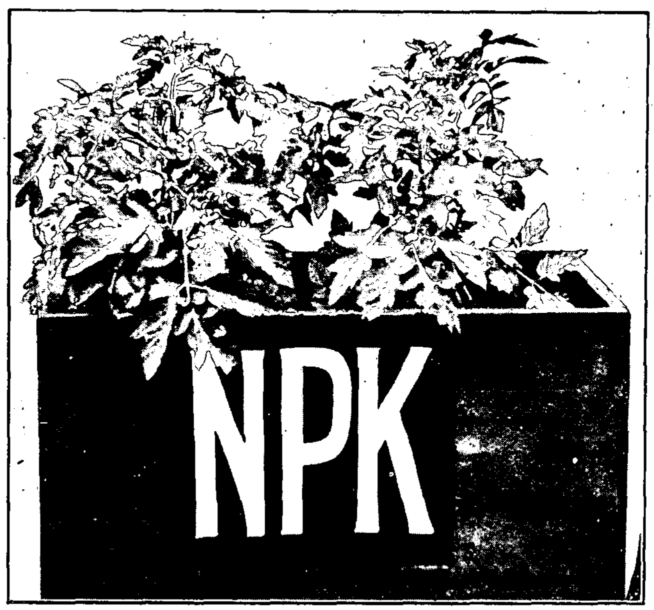

FIG. 3.

for ascertaining deficiencies. It would not be amiss to mention the words of Albert Bruno in a communication during the 12th International Congress of Chemistry at Prague, when he said:—

> "It is not unreasonable that we should put soil analysis amongst the illustrious series of errors of agricultural experimentation. We point out that the chemical analysis of the soil is without doubt of comparative value, and valuable as a control. The error has been to look for more than could be expected from it. The greatest mistake has been to assume that a dry pulverised sieved matter, enclosed in a glass bottle, should still represent the soil as it was, and by submitting such matter to purely chemical, physico-chemical or even bio-chemical methods, one could draw conclusions valid enough to give precise indications in the use of fertilisers."

Professor Remy also, in a lecture given to the Scientific Department of the German Potash Syndicate on the value of soil analysis for the determination of soil requirements of fertilisers, points out the following facts:—

1. Fertiliser requirement of the soil: $D = N - Z$, N being the nutrient requirement of the plant and Z the available nutrient supply from the natural reserves of plant-food occurring in the soil.
2. $N = E \times G$, E being the yield and G the percentage plant-food content of the produce.
3. $Z = A + Aw$, A being the amount of plant-food available at the beginning of growth and Aw the amount of plant-food becoming available during the growing period.
4. Of all these factors, at the best only one, A, can be determined accurately, by chemical methods of soil investigation.

Taking these fundamental points into consideration, Remy classed the arguments against basing fertiliser recommendations on chemical soil analysis under the following six headings:—

1. The fertiliser requirement of a field is dependent on the coming crop yield, which cannot be determined at the time of making the analysis.
2. The available nutrient supply from the natural plant-food reserves in the soil varies from year to year and cannot be estimated in advance.
3. Within one field the composition of even the surface layers of the soil often varies so greatly from place to place that an average sample of the whole field can give no idea of the amount of available nutrients which the soil in different parts of the field is capable of supplying to the crop.
4. The crop obtains part of its nutrient supply from the sub-soil, of which the content of available plant-food may differ greatly from that of the soil layer analysed.
5. The fine earth, to an examination of which the analysis is confined, is mixed to a varying extent with coarser soil particles, which do not partake in the supply of nutrients to the crop.
6. Thus the effect of fertiliser applications depends on different mutually independent factors, and cannot therefore correspond to the content of available plant-food of a fine earth sample as determined by laboratory methods.

As Potapov says in an article, "Soil Acidity as a Phytopedological Factor," the old Russian school of soil scientists thoroughly worked out the principles of genetic pedology, based chiefly on morphological and but partly on chemical properties of soil horizons. In more recent years, as a result of investigations in the United States, in England, in Germany and elsewhere, on the role of micro-organisms in the soil, an extensive and very fruitful biological trend was created in soil science, while by ascertaining the role and importance of the soil absorbing complex, a new branch of science, which can aptly be termed Soil Physiology, has been created. But the surface vegetation has been, so far, studied mainly by botanists, and consequently its importance as a factor in soil formation has appeared to be of less significance than it really is. Because soils were studied independently from plants we failed to appreciate the laws governing the close relationship between plants and soil which exist in nature. And since all problems of agronomy may eventually be reduced to the question of the relationship between plants and soil, the importance of the said branch of science becomes most obvious.

The modern method of ascertaining the plant's requirements is to study the plant ecologically.

Lagatu and Taume have, for some time past, been studying the relationship between the plant's requirements in certain elements and the quantities of these elements contained in the leaves at the base of the fruit-bearing branches of the vine. They found definitely that they could detect distinct deficiencies in the leaves and, in fact, total absence of some of the essential elements when badly balanced fertilisers were used, with the consequence that on some of the plots where potash, for instance, has been left out, there were not one but several pathological symptoms. *It may be maintained, therefore, that the plant itself is an excellent medium for the study of its own requirements*, and in this connection I would like to pass you one or two photographs which show definitely the plant's reaction to the elements necessary for its maximum development.

The tomato plants were all planted the same day, and were all given the same quantities of water.

Fig. 1.—O = control.

Fig. 2.—NP = the equivalent to 500 lb. superphosphate, 300 lb. sulphate of ammonia.

Fig. 3.—NPK = the same as NP plus the equivalent of 200 lb. sulphate of potash per acre.

The results are what might be expected in a soil of that description, namely, a red Berea sand.

Regarding the variations in the figures in Dr. Hedley's and Mr. Beater's paper, these may quite possibly be due to differences in the soil. It is mentioned that however well the samples may be chosen, these variations cannot be eliminated. We know perfectly well that this country is made up of soils that vary enormously, and this is another reason why the study of the soil forms one of the most important subjects in agricultural research. Plants do not draw all their nutrients from what may be designated the surface soil; they may take it from any horizon which is within their reach. The soil is to be divided up into roughly three horizons, A, B and C; A being the elluvial horizon, which in some cases may be designated as the surface soil or a layer from which substances have been washed out during soil formation, either by chemical or mechanical means, and it is this layer which may sometimes become very strongly podsolised. B is the illuvial horizon, which is formed of deposited material, either by chemical or mechanical means, such as sand, or pan formation (lime concretions); iron pans often occur in this horizon. C, the horizon of undecomposed mother rock from which the soil is presumably formed.

In the paper which has just been read, it may be noticed that the quantities of P_2O_5 absorbed are in all cases distinctly below K_2O and N.

This was to be expected from all other available data, in this respect; and in addition it is interesting to note a statement from Puerto Rico, that 105 lbs. P_2O_5 were actually found to be detrimental to the growth of cane.

Here in South Africa it has been noticed that large quantities of this substance can be used profitably on cane; but I would like to point out that in mentioning these very large quantities, no mention is ever made, or seldom so, of the soil type. You have on the coast very large areas covered by doleritic soils, sometimes quite heavily laterised, a laterite soil being the product of a hydrolysis of a silicate promoted by high temperatures. It is first and foremost felspars which are subject to laterisation. Felspars are silicates of potassium and aluminium. The red colour is explained by the bleaching influence of the humic acid which dissolves the iron oxide or hydrate, as one can notice very often in marshy land. This leads me directly on to the subject of what becomes of the P_2O_5 in a fertiliser when it is added to such a soil. This would indicate that in some of the soils of this country large quantities of P_2O_5 may become unavailable through being transformed into insoluble iron and aluminium phosphates. In Science Bulletin 110, written by the well-known chemist, C. O. Williams, late of Cedara, it is pointed out that the above explanation "is doubted and even contradicted by many scientific investigators," but he continues to say, "the fact remains that this type of soil does quickly render insoluble the readily soluble phosphates that may be added to it." To illustrate the point, I shall continue to quote shortly some experiments carried out by Mr. Williams at Cedara in this connection. By taking a certain amount of soil of the red type, adding a small quantity of superphosphate with some water, and shaking it from five minutes to one hour. It was found that in five minutes 60% of the water-soluble phosphate was unavilable, and in one hour 90% was insoluble in water. When a 1% citric acid solution was used instead of water—which is, as you know, the method used in determining the available quantities of this ingredient in the soil—after five minutes it was found that 45% of the available phosphate was insoluble, after half an hour approximately 60%, and in 24 hours 80% was insoluble in the citric acid solution.

The third experiment consisted in putting a small quantity of soil into a mortar, and mixing it thoroughly together with superphosphate and water, with an addition of burnt lime and potash salts in some cases, and this mixing was continued for different periods of time. The results showed that the whole (100 per cent.) of the water-soluble phosphate of the fertiliser had become insoluble. Also, about 83% of the soluble phosphate of the superphosphate became unavailable, as measured by the citric solubility test described in the second series of tests.

This would be an explanation for the possible use of large quantities of P_2O_5 from an economic point of view. The larger applications would saturate the Fe_2O_3 and alumina and affect the crop beneficially. The quantity to obtain the best effects would from this point of view depend on the point of saturation.

I had a similar experience with an experiment on cane on a doleritic soil. One section of the plots received the whole dressing of fertilisers three weeks before planting, and I noticed that for a while those plots which had had only superphosphate, were but little better than the controls. Was this a matter of availability?

The whole of this question of soil in relation to plant growth requires a great deal of study, and if we work judiciously we shall learn a lot and perhaps even modify our times of application of certain fertilisers for cane. But the essential factor for successful research is not to allow ourselves to become one-sided, but to include all aspects of the problems under investigation.

Dr. HEDLEY: Is it competent to discuss a discussion? I will not take up much of your time, but I would like to say this, that I think Mr. Lintner's paper was a far better paper than mine. I would like to thank Mr. Lintner for his discussion of my paper, and to say that I am certain that his discussion was far better than the paper which brought it forth. (Applause.)

Mr. LINTNER thanked Dr. Hedley, and pointed out that it was far easier to discuss the paper than to do the 150 analyses!

Mr. DODDS: I am very pleased to see on record at last this work which Dr. Hedley has done. It is a work which wanted doing for a very long time, but as it was of a very tedious nature it has not been undertaken before in this country. It is on record in other countries, for example, in Stubbs' "Sugar Cane," in which some excellent pioneer work was recorded on this matter many years ago; and others have followed with similar analyses since, which are of very great interest.

At first sight one would imagine that the prime need of our soils must be potash, to look at the very high potash contents of the plants compared with other minerals and recorded in this paper. But field experience tells us that it is not so and these compositions cannot be regarded as a sole index to the requirements of the soil. To study these adequately we must refer to the soil itself also. I agree with Mr. Lintner in that

I think that in the past far too much stress has been placed on the results of soil analyses taken by themselves without any further evidence; but nevertheless there is considerable value in soil analysis if other avenues of information are taken into account, such as results of field experiments and the composition of the plant at different stages of growth. That brings me to another point which needs to be followed up, but unfortunately needs an even greater number of these very tedious analyses, that is, the analysis of the cane at different stages of growth. We have evidence that in the smaller grasses there is considerable seasonal variation; for example, young grass is much more nutritious than old grass, not only because of its greater digestibility, but because of the fact that it contains far more minerals in its early stages than it does later on. Whether the same can be said of sugar cane nobody seems to know for certain, but there is evidence to indicate that such may be the case. I agree with Mr. Lintner that these wide variations in the composition of different stools of Uba cane should not be dismissed as unaccountable errors of experiment; the experiments themselves, as Dr. Hedley remarks, were very concordant in duplicate tests on the same samples. There must be some reason in the soil or in some other condition or environment position, and it is very much to be desired that the nature of these differences and underlying causes should be determined. With regard to the overwhelming need that we have found for superphosphate in our soils, I do not think there is any getting away from that fact. Experiments carried on all over the country show a response to phosphate, preferably in most cases superphosphate, in almost any quantity. I think if it was merely a particular case of base exchange and that a certain amount of superphosphate had to be added to fix the iron, you would only get a response from relatively larger dressings of phosphate after the iron had been all combined; but we find that is not the case. We find that even small dressings of superphosphate are good, but moderate dressings are better, and heavier dressings better still. That is the result of our experimental work up to the present. We have not yet been able to find what is the maximum economic amount of superphosphate to apply, although we had some indications in our experiments at Empangeni last year, where we found 1,000 lb. per acre of superphosphate gave results not very much better than 750 lb. That, however, was only on the plant cane crop, and we need to follow up the result in the ratoon crops before we can come to any conclusion about that. I feel sure that a Planter cannot go wrong in applying heavier dressings of superphosphate than he has been accustomed to in the past. Conditions in most other countries are entirely different. We have an example of that in the Clarification report this morning. You will notice on page 4 of that report that Walton and Fort found in America a minimum $P_2O_5\%$ brix of 0·38 where the South African minimum was 0·09, and a maximum of 0·53% where the South African was 0·112—only a quarter as much. That seems to indicate very clearly the phosphorus deficiency in our soils. No doubt potash is required to a considerable extent in many of our soils, but I do not think it is fair to deduce from the analyses of cane that such very large quantities are required as might be supposed from these records. After all, the amount of total potash in any soil is very great relative to the plant's requirements and can only be influenced to a very slight extent by any practicable addition of potassic fertiliser. What one does affect is the available potash in the soil, the amount which is in the form the plant can take up, and that can be supplied not only in the form of fertiliser but by other means such as cultivation, liming and growing of green manure crops and the like, to promote the transformation of some of the reserves of available potash into more available forms, and especially by the application of waste products from the factory, such as molasses. (Applause.)

CHAIRMAN: It is a pity we have not further time to discuss this very interesting subject, but I would suggest that any further discussion on phosphates be reserved for the meeting to-morrow night with the Chemical Institute, which I hope will develop into a general discussion on phosphorus.

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