CELOS bulletins

no. 26

A DOUBLE POT TECHNIQUE FOR RAPID SOIL TESTING

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Reprinted from:

Tropical Agriculture (Trinidad), 51 : 161-166 (1974)

A double pot technique for rapid soil testing

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A pot experiment technique was developed for rapid identification of the nutrients which are in short supply in soils. The principle is that young plants can take up nutrients simultaneously from the soil to be investigated and from a nutrient solution. When a nutrient is omitted from solution, plants can take it up from the soil only. The difference in growth between plants on a deficient and on a complete solution, expressed as the so-called 'sufficiency quotient', is an estimate of the availability of the relevant nutrient in the soil. Some experiences with different nutrients and with different crops are discussed.

INTRODUCTION

The study of soil fertility, in the restricted sense of the supply of nutrients to plants, proceeds in two steps. First, it should be determined which nutrients are limiting growth and second, what quantities of fertilizers should be added to eliminate the deficiencies.

Several research methods are available. They range from field trials to chemical and microbiological laboratory procedures, each of which has its merits and drawbacks.

Field trials most closely approximate to agricultural practice, and hence, they form the ultimate test for any other technique. Disadvantages are the high costs of labour, time and land, and the large variability in results owing to differences in external conditions such as weather, pests and diseases.

Chemical analysis of soils and plants has the merits of rapidity, accuracy and relatively low costs. Its weak point is the dependence of its usefulness on a knowledge of the relationships between the chemical data and the responses of crops to fertilizers. These relationships vary from crop to crop and from place to place. This confines use of the method to areas where a great deal of research has already been done.

Pot trials take an intermediate position between field and laboratory trials; in common with the latter, soils are not used *in situ* and thus difficulties that may arise in the layout of the experiments in the field are avoided. The analogy with field trials is that the actual plant is the medium of study and that the method does not require a laboratory.

In developing countries it is often impossible to use the chemical method either for lack of laboratories or for lack of knowledge of the relations between plant and chemical data. In such situations field trials are indispensable. However, where it has to be decided whether or not to clear forest land or develop

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otherwise inaccessible areas, field trials cannot be carried out beforehand to furnish the decision information. In such cases pot trials show a clear advantage.

The demands for labour, soil and time associated with the classic pot trial techniques are high enough to make it worthwhile to look for methods that can reduce these demands. Based on and derived from the studies described by BOUMA (1965) and BOUMA and DOWLING (1962; 1966a, b) such a method was developed by JANSSEN (1970). The method is thought to be especially useful for the identification of the nutrients that are in short supply. Thus it may serve as a guide to reduce the number of field trials and as an aid to laboratory and field studies.

DESCRIPTION OF THE TECHNIQUE

Principle

The principle of the technique is that young plants can take up nutrients simultaneously from the soil to be investigated and from a nutrient solution. A schematic section of the equipment is shown in *Figure 1*. The pot, which has a gauze bottom, is filled with soil (say, 200 g). Seeds or seedlings are planted in the soil. Their roots pass through the gauze and reach the nutrient solution in the container below. When a nutrient is omitted from the solution, plants can take it up from the soil only. The difference in growth between plants on a deficient and on a complete nutrient solution is a measure of the availability of the relevant nutrient in the soil.

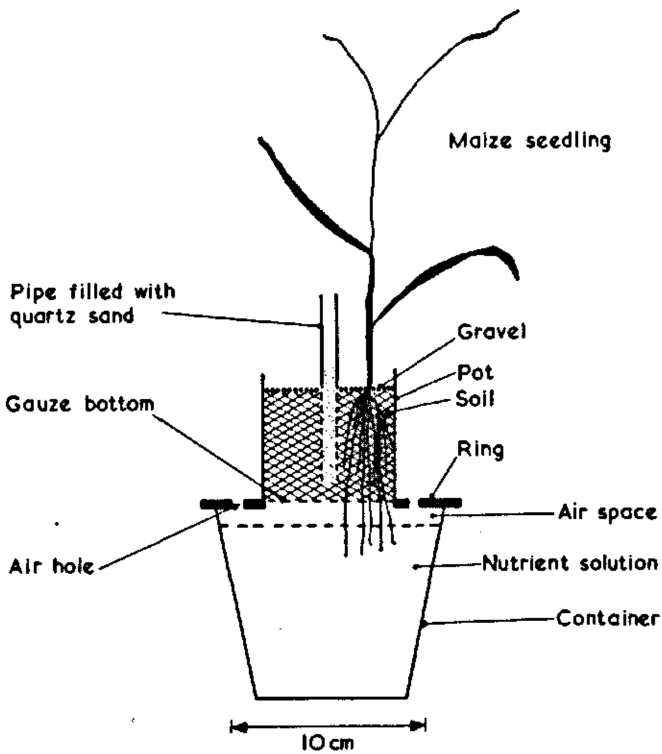

Figure 1. Schematic section of the equipment

Growth measurement

The basic method of measuring plant growth is to determine dry matter increase. The procedure requires many replicates, since for each intermediate dry matter determination a complete set of plants has to be harvested and weighed. When growth of the same plant is followed, the number of replicates can be reduced because the variability in growth between plants is eliminated.

A parameter of plant growth which avoids the need to harvest the plants is the increase in leaf area or leaf length. In the case of Gramineae, it has been found convenient to measure the lengths of the leaves from the base (soil) to the apex, that is blade and sheath. The sum of the lengths of the individual leaves, termed plant size, S, and the relative increase in plant size per unit of time, t, was used as the plant growth parameter, R_S. Therefore

$$R_S = \frac{1}{S}\,\frac{dS}{dt} \tag{1}$$

The parameter R_S is comparable with the well known relative growth rate (RGR or R_W) and the same growth functions as developed for dry matter increase are applicable (a recent review was given by EVANS, 1972).

Integration of equation (1) between t_1 and t_2 gives:

$$R_S = (\ln S_2 - \ln S_1)/(t_2 - t_1) \tag{2}$$

Equation (2) gives the mean value of R_S in the period of t_1 to t_2, which is identical with the actual value of R_S at any instant only under conditions of experimental growth.

Sufficiency quotient

As index of the difference in growth between plants on a deficient and on a complete solution, and hence of the difference in nutrient availability, the so-called sufficiency quotient (SQ) was introduced, i.e.,

$$SQ_P = \frac{(R_S)_{-P}}{(R_S)_C}$$

where SQ_P = sufficiency quotient for phosphate, $(R_S)_C$ = relative increase in plant size per unit of time of plants on a complete solution, $(R_S)_{-P}$ = relative increase in plant size per unit of time of plants on a solution without P.

When the value of SQ is unity, the availability of the nutrient in the soil is as high as that in the solution.

Figure 2 illustrates the foregoing. Plant size values were plotted against time on semi-logarithmic paper, so the slopes of the curves are: $(\log S_2 - \log S_1)/(t_2 - t_1) = 0{\cdot}434\ R_S$. SQ_P is the ratio of the slopes of the growth curves for the plants grown on the P deficient and on the complete nutrient solutions.

It can be seen also that the value of SQ depends on time, so that it is necessary to standardize the time interval in which SQ is determined. For wheat the interval between the two leaf stage and the point of tillering of the second axil of the main shoot, i.e., about between day 10 and day 19 after sowing, proved

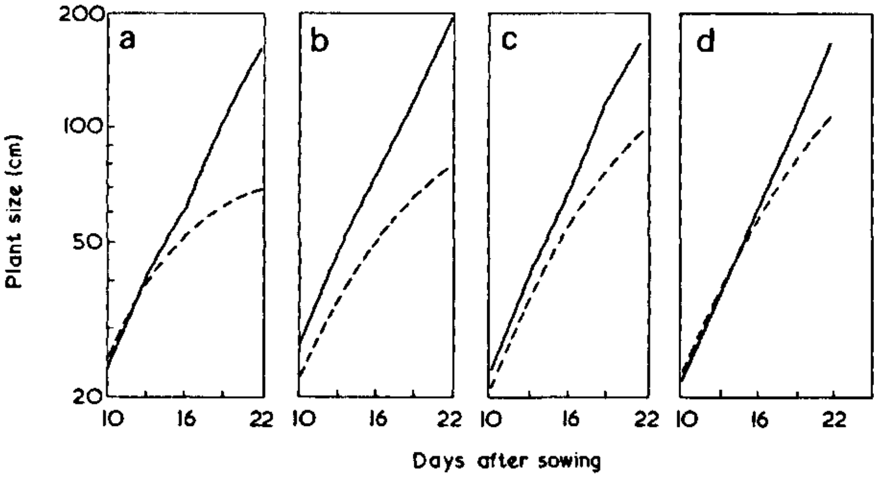

Figure 2. Growth of plants on soils of different phosphorus content. P_2O_5 content (as determined from Al–P extraction with ammonium lactate–acetic acid) in mg/100 g soil: (a) *6 (SQ_P = 0·48);* (b) *13 (SQ_P = 0·63);* (c) *19 (SQ_P = 0·80);* (d) *22 (SQ_P = 0·81). ———, Complete solution; - - - - - -, solution without P*

most appropriate; for maize it was the interval between the four leaf and the eight leaf stages, i.e., between day 10 and day 17 after sowing.

RESULTS AND DISCUSSION

So far, most experience has been obtained with wheat and maize. Maize proved more useful as a test plant than wheat.

The results were very satisfactory for nitrogen. SQ_N was almost linearly related to nitrate-N in Turkish soils. Both in Surinam and in Turkey, SQ_N was correlated with the contents of organic matter and of total nitrogen. The SQ_N values were in close agreement with the results of field trials (JANSSEN, 1970, 1973a).

For phosphate the situation was more complicated. Only where differences in phosphate availability were very large could they be demonstrated (*Figure 2*). The variability among replicates was rather high and the correlation with results of field trials and chemical analyses was poor. This disappointing experience was ascribed to uneven distribution of soil phosphate, slow transport of phosphate through soil and its dependence on soil moisture conditions.

Potassium deficiency was indicated more clearly by maize than by wheat. In Surinam soils, a correlation was found between SQ_K and exchangeable potassium.

Experience with secondary and minor nutrients is still limited. Special problems arise such as stunted root growth in solutions lacking calcium, enhanced availability of manganese by the pretreatment of soils (drying), and very slow translocation in plants (e.g., boron). It seems that magnesium deficiency can be detected by the method.

Crops other than maize and wheat which have been successfully submitted to the described technique are tomato (MATHIJSSEN, 1972), *Pinus caribaea* Morelet (JANSSEN, 1973b) and cacao (MULLER, 1973). Since calculation of

SQ is not feasible for these crops, growth differences were expressed in dry weights of the plants at the end of the experiment, or in a 'growth index' (MULLER, 1973). Some experiments were intended merely to show visual symptoms of deficiency.

So far it seems that the main value of the double pot technique lies in its use as an indicative soil testing method. It may provide quantitative estimates of nitrogen and potassium availability. For all nutrients the method is very appropriate to serve educational and demonstration purposes.

The main advantages of the sufficiency quotient as an availability index are its suitability for any nutrient and its small variability, which is to be ascribed to the elimination of differences in germination.

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DISCUSSION

G. T. Felbeck:– Was the height of the plant the sole criterion used to determine the growth rate of the plant?

Author's reply:– Yes and no. It was permissible to use the sum of leaf lengths = plant size because we had found good relationships between plant size and dry matter.

G. T. Felbeck:– How was the water content of the soil controlled?

Author's reply:– The water content was kept at field capacity (about p*F* 2·0) by daily additions of water through the plastic pipe. Moisture losses were measured by weighing. Evaporation was suppressed by a 0·5–1·0 cm thick gravel layer on top of the soil. If necessary, water was added twice a day, the second time at a fixed quantity of 10 ml.

G. W. Morgan:– You used maize as your test crop; do you think more precise results might be obtained by using a plant with a smaller seed which would have less nutrient reserves?

Author's reply: – Until now the choice of crop has been based on their agricultural importance (wheat in Turkey, maize in Surinam, subterranean clover in Australia). In the Netherlands recently experiments were performed with tomato.

Your suggestion to use small seed crops, however, is very worth while. The same idea underlied Ehrendorf's shifting from rye to lettuce in Neubauer's seedling technique.

The plant chosen should meet at least two requirements: (1) germination should be regular; (2) there must be an 'easy' parameter like leaf length or leaf area to measure plant growth. If not the number of replicates has to be at least doubled.

W. E. Nelson: – In view of there being so much variability between different soils did you measure any soil parameters and examine whether or not there is any correlation between any of these parameters and the results you obtained?

Author's reply: – Only from a few Surinam soils do we have both soil parameters and SQ values. There was a relation between organic matter and SQ_N and between exchangeable K and SQ_K, but not between P-Bray I and SQ_P.

In former research in Turkey we found that the relation of SQ_N was better with NO_3-N than with total N or with organic matter. Thus far SQ_P could only be related to Al–P (ammonium lactate and acetic acid) in Dutch soils from P field trials. In Turkey no relation between SQ_P and P-Olsen could be found but the investigated soils were all low in P, so that the range of P-availability was not wide.

The intention of the technique presented is not to replace chemical analysis but to be helpful in interpretation and to be a possible way to get some indications on soil fertility where chemical analysis and/or field trials are not feasible.

J. Lucas: – Did you try to establish correlations between the RGR using length indices and RGR using changes in weight of dry matter?

Author's reply: – For wheat there was a linear relationship between 'plant-size' (sum of leaf length) and dry matter, roughly: $S = 8W$ where S = plant size in mm and W = dry weight in mg. The relation holds up to about $W = 300$ mg. So $RGR_S = RGR_W$. For maize it was found: $S = 40\ W^{0{\cdot}58}$, so $RGR_S = \ln\ [40\ W_2^{0{\cdot}58} / 40\ W_1^{0{\cdot}58}] = 0{\cdot}58\ RGR_W$.

In the sufficiency quotient the factor 0·58 is dropped (nominator and denominator) so that: $SQ_S = SQ_W$.