SESSION 7

EVALUATION OF METHODS OF SOIL TESTING BY MEANS OF FIELD EXPERIMENTS

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All modern methods of soil testing are designed with a view to determining the nutrient available to the crop in agricultural practice. In so far as they are chemical methods, the chief aim is to determine the fractions which are easily soluble.

The reliability of a method should never be taken for granted *a priori*. This even applies to a method like the pot experiment according to MITSCHERLICH. To accept such a method as normative, as was formerly done in comparing methods carried out under the auspices of the International Society of Soil Science, really means the denial of the significance of interactions between the factors tested and all other factors determining the growth of the crop in farming practice. Such methods are only acceptable for a first orientation. It should be realized that a method of soil testing must be entirely based on actual agricultural practice.

It has been said that soil testing will never be able to ascertain the availability for a given crop, the more so as interactions between a particular factor and other practical factors in a specific case cannot be denied. However, the important point is whether the results of the soil test obtained are connected with the reaction of a crop in such a way that advice can be based upon them, which fulfils practical requirements in a given agricultural situation. Moreover, it is a misappreciation of the possibilities of research to deny that interactions with other factors can to some extent be distinguished and can be implicated in the evaluation.

The requirements a method should fulfil vary from case to case. The chief point is the aim and object in a specific agricultural situation. Wherever farming is extensive or may be considered as little developed, it may be sufficient to trace the more conspicuous defects. A close observation of the crop will in such a case possibly provide an adequate test for a method. In a form of progressive farming producing all but optimum yields, it is rather of importance to efficiently apply the available fertilizers and to improve the quality of the produce than to increase the yields. In this case accurate testing of a method will be essential before it can be recognized as efficient. In the various countries situations between these two extremes are numerous. The fact that in the Netherlands with its intensive and rationalized agriculture heavy demands are made on the usefulness of a method has no doubt been the reason that more attention is paid to the evaluation of soil testing than elsewhere. Therefore I venture to ask your attention, presently, for the discussion of a specific example of evaluation of soil testing in the Netherlands.

The chief requirement of a soil test lies in its effectiveness in indicating what fertilizer is needed and in what quantity it will have to

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applied to a particular crop, or to a complete crop rotation.[1] This standard demands a testing of a method against the reaction of the yield of one or more crops to the soil factor concerned and the quantities of fertilizers applied. Trials of one year's duration are very suitable for the purpose. To arrive at a more reliable average reaction, this research will have to be repeated in other years and on different trial-fields.

Though it is the agricultural aim to increase the yields, one cannot say that difference in yield is necessarily the most exact standard for measuring prevailing differences in the soil. All sorts of inaccuracies may be inherent in a considerable measure, which have little connection with the physiological reaction to the availability of a soil factor. Besides, the accurate determination of differences in yield requires field-trials that are fairly extensive. Moreover, difficulties may occur in the case of perennial crops or crops producing more than one yield a year, such as grass. Differences in vigour of the crop, in extent of tillering, or content of nutrient absorbed in a plant, etc., will sometimes more directly (and in a manner less influenced by secondary factors) mark the unequal availability of the soil factor. In this way more suitable data may often be obtained to disentangle the influences of various factors. Thus there are simpler methods than the performance of accurate field-trials. A great number of observations, often obtained without much elaboration, may render great accuracy less necessary. Adequate data are often obtained on simple trial plots or on observation spots.

Where particular methods are compared, the method showing the clearest relation to the reaction of the crop will be the best. However, this only applies to these special circumstances. It must never be concluded that some method is absolutely and exclusively the best. For example, in the Netherlands two methods for phosphate determination are employed. In one method the solubility is determined in warm water (50°C), in the second it is determined in 1% citric acid. It was proved that differences in availability of phosphate in a homogeneous soil is often much better indicated by the water method. Nevertheless the citric acid method is more satisfactory in comparing soils of a different nature. The water method is now only applied to one particular homogeneous type of soil.

It should be considered that the value of a method may greatly vary according to the kind of soil. This will be the result of the interactions of the particular single value with other factors on these soils. A phosphate value determined with citric acid must be, for example, 2½ times as high on peaty grassland than on loess grassland for an adequate nutrition of the grass. It is therefore extremely risky to apply methods which proved suitable in a certain area to a different region without further investigation.

However, if the investigation is confined to a comparatively homogeneous soil, it will often be possible to determine the remaining

[1] Besides, it is of importance to find the best fertilizing systems in order to maintain an existing manuring status for a long duration, or to raise it to a more economical level. This problem is mentioned only parenthetically. It may necessitate a further research, e.g., the development of methods for the determination of the fixation of phosphate and potash and the testing of these methods in long-term field-trials.

interactions with accuracy and to incorporate them in the evaluation of the particular single value. This has opened up the possibility of refining the interpretation of soil testing to a remarkable extent.

It is difficult to say what limitations should be observed in respect to the soil area in which a method can be tested. It seems advisable not to start with too extensive and too heterogeneous areas. Soils that do not show very much variation, could be chosen as objects of an investigation. The results of different regional investigations could be compared and combined afterwards. But in due course all the important agricultural soils will have to be tested.

Investigation was often begun by an attempt to find out whether differences prevailing on trial-fields can be demonstrated according to a method and the number of "strikes" was taken as a measure for its practical usefulness. This procedure is rather crude, however. The chief point is to determine whether a certain figure in one field represents an equal or a different value compared with the same figure on another field where the soil conditions are not the same (allowing for interactions and their effects eliminated). The method can only be employed if the results are applicable to an area of some extent. The certainty should exist that the method also holds good for extreme situations in this region.

What has been said will remain vague unless it is elucidated by an example. Therefore I will discuss one of the series of field-trials which have been laid out to test the K-value on marine clay soil. Corresponding investigations have, with interruptions, been carried out since 1936, both relating to arable land and grassland, especially as far as phosphate and potash are concerned. The example chosen is illustrative, because in evaluating the K-value (K-content in 0·1 N HCl in the case of 1 part of soil to 10 parts of liquid) it is mostly necessary to consider some factors simultaneously.

In designing such an investigation the data obtained in another way will often be a great help. It is well known that in many crops the effect of potash is physiologically determined by the lime status of the soil. Furthermore the base-exchange capacity of the soil, which depends on the clay and humus contents, determines the availability. Care should therefore be taken that at any rate these factors are correctly implicated in the investigation.

The trial-fields must be selected in such a way that a considerable variation occurs in the potash value together with the other factors mentioned. The selection therefore requires preliminary soil testing. If in the region intended for experimentation, large-scale soil testing for farming practice was previously carried on, the resulting data may be a great aid in making a decision on what fields are to be selected.

The number of trial-fields required for a successful treatment, depends on the number of factors which are expected to be influential, the extent of the correlations between these factors and the extent of their effects and their interactions. Experience has taught us that at least some tens of trial-fields are necessary for a limited district.

Care is taken that the distribution of the trial-fields is relatively even, i.e. as much as possible in equal measure fields should be selected which are poor, moderate or rich in potash (and also poor or rich in lime, clay or humus), even if these categories are rare in the particular region. Moreover it is tried to avoid correlations between the principal factors to be studied. If, for example, there is an evident correlation between potash content and clay content, yet an attempt is made to select the trial-fields in such a way that both at a high and at a lower potash content sufficient variation in the other factor occurs and *vice versa*. Another aim is to acquire a regular distribution from a geographical point of view.

Fig. 1 shows an example in which the fields intended for experimentation have been selected from results of soil testing. The choice was made by plotting the potash value both against the lime content and the clay content (particles less than 16 μ) and also the latter

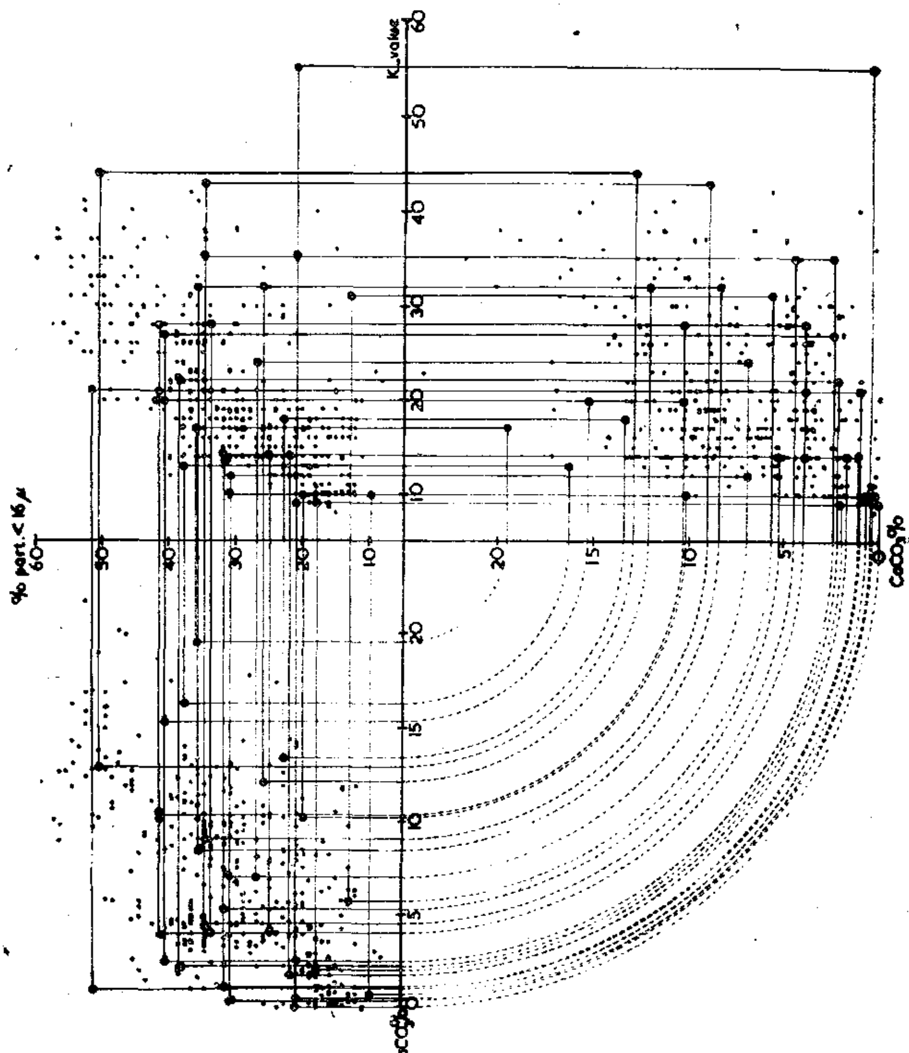

Fig. 1.—Selection of trial-fields after regional soil testing eliminating correlations of factors and aiming at a regular distribution. Dots represent results of soil tests. Large dots represent selected trial-fields.

against each other. If 3 factors are taken into account, the cases selected for the laying out of a trial-field, will, therefore, have to be evenly distributed over a cube.

The investigation in question was carried out in 1947 and 1948 in the largest polder (Haarlemmermeer) of the province of Noord-Holland with comparatively small series (18-20 experiments). In 1950 it was continued in other polders in Noord-Holland.[2] Our attention will chiefly be confined to this last year. Then there were 33 trial-fields under potatoes, variety: Bevelander (just as in 1947 and 1948), besides in one of the polders (Heer Hugo Waard) a series of 27 trial-fields carrying the variety of Eersteling. The two series of trials were studied independently.

The lay-out of the trial-fields was simple. Each field comprised 10 plots, of 25 square metres each. Four plots received no dressing of potash, the other plots, in pairs, 60, 150, 300 kgs/ha.K_2O as sulphuric potash.

The K-value was tested by:

(1) The increase in yield of tubers resulting from manurial treatment;
(2) The K_2O-content of the tops of fairly young plants;
(3) The K_2O-content of the tubers;
(4) The under-water weight of the tubers;
(5) The actual yields.

The increase in yield as a result of manurial treatment was indicated in the yield which is obtained without K-treatment, expressed in percentages of the yield that is obtained on the plot of the trial-field with the highest K-dressing. In employing this "relative yield" it is assumed that in applying a heavy K-treatment the need of potash on this soil is completely supplied. The first two experiment years were successful in this respect, but, as we shall see, not the experiment year 1950.

The K_2O-content of the potato tops gave the most evident indications, so that this tends to receive special attention. The easy method of determining the under-water weight also produced satisfactory results.

The relation between the K-value and the potash content of the potato tops from the Bevelander plots which received no potash dressing, is shown in fig. 2a.

Fig. 2b shows the same, after the effects of the factors clay content and lime content have been eliminated (the method of elimination will be discussed later). It appears that, allowing for these factors, a close relation exists.

The determination of the effects of the various factors is made successively, the strongest influences generally being analysed first.[3] After the influence of the K-value is provisionally determined by a free-hand curve (fig. 2a), the influence of a second factor is determined. This influence is also graphically determined after the influ-

[2] The investigations have been performed by the Agricultural Services in the Province of N. Holland.

[3] This method (called polyfactor analysis) is due to W. C. VISSER. It has been applied in even far more complicated cases. Much attention is now being paid to its mathematical foundation.

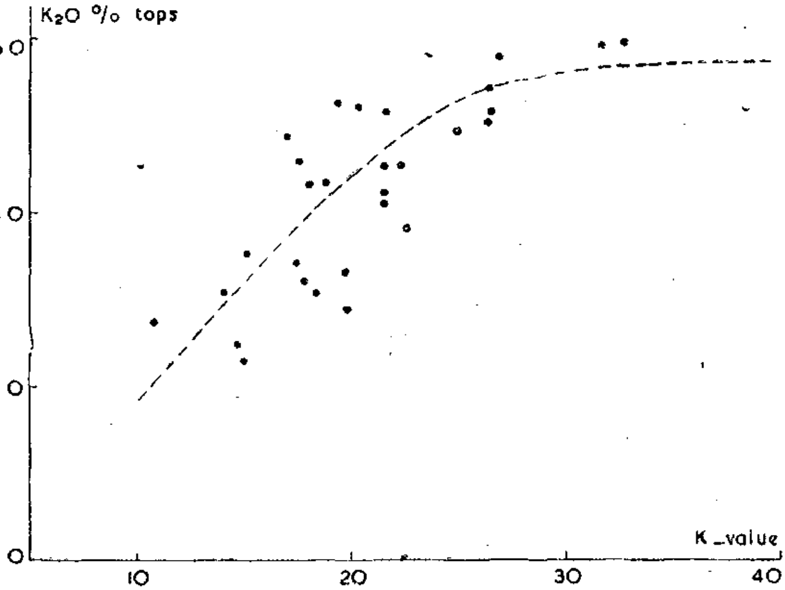

Fig. 2a

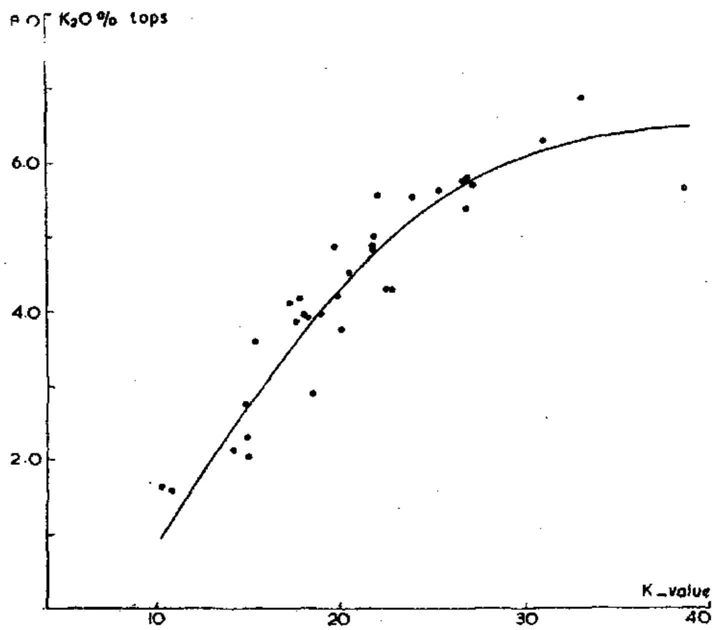

Fig. 2b

Fig. 2—Relation between K-value of the soil and the K_2O content of Bevelander tops: (a) before, (b) after elimination of the influences of lime status and content of particles $< 16\mu$.

ence of the K-value has been eliminated. In the instance in question this was done by plotting the distances of the dots of the curve in fig 2a, measured in a direction perpendicular to the absciss, against the second factor. A dot above the average curve indicates that the uptake was better than the average; a dot below it indicates the reverse.

Interactions between the factors are established as much as possible. If the extent of the material permits it, it is divided up into two or more groups of different K-values and this procedure is followed in these groups independently. In fact, it is very likely that the influence of the second factor on the K_2O-content of the potato tops (or something else) will be different according as the K-value of the soil itself is high or low.

If the influence of a second factor on the K_2O content of the tops is determined in this way, it can be eliminated. Then the influence of the third factor is determined in the same manner. If this has been found, corrections can be made again. The corrected K_2O contents are plotted against the K-value in fig. 2b. Moreover, it is possible to establish more accurately the influence of the second factor after elimination of the influence of the third factor, etc.

The relation between the lime status (here indicated as lrb-value[4]) and the deviations from the dots of the average curve (fig. 2a) has been separately demonstrated in figs. 3a and b for a low K-value (<20) and a high K-value (>20). In this case also the influence of the third factor (content of particles less than 16μ) has been eliminated.

The influence of the lime status is different in either case. At a low K-value the K_2O content appears to have been strongly affected by this. High K_2O contents have occurred on decalcified soils, low contents on moderately calcareous soils. At higher lrb-values there is a rise. Such a complex relation has frequently occurred in other series of potash experiments. There is little doubt that in case of an increasing lrb, decreasing K_2O contents are to be attributed to a lime-potash antagonism. It is less easy to give an explanation of a rise in case of a higher lrb.

In case of higher K-values, at which potash is to a less extent a minimum factor, only a slight indication of an influence of the lime status is found (fig. 3b).

The influence of the clay content appears from fig. 4. It was impossible to distinguish an interaction, so that all determinations have been used. In this figure the influences of the K-value and the lrb have been eliminated. Soils with a higher clay content have yielded lower K_2O contents of the tops than lighter soils.

[4] The pH is not a very suitable measure to indicate the differences in lime status of calcareous soils with some accuracy, because soils with varying contents of $CaCO_3$ are only slightly different in pH. On the other hand the $CaCO_3$ content is zero on decalcified soils. VISSER introduced the lrb-value (logarithm relative base content, $\text{lrb} = \log \frac{S + 20 \times CaCO_3\%}{T}$. The numerator is determined by measuring the neutralization of added 0·1 N HCl; T = sorption capacity in equilibrium with a surplus of $CaCO_3$) which can be determined in either case and connects the decalcified and calcareous soils in one scale. On soils in a neutral condition practically without $CaCO_3$, lrb = O. Decalcified soils give negative values; those containing $CaCO_3$ give positive values. On a soil with 1% $CaCO_3$ lrb = ca. 0·2; the lrb = ca. 1·0 on a soil with 10% $CaCO_3$.

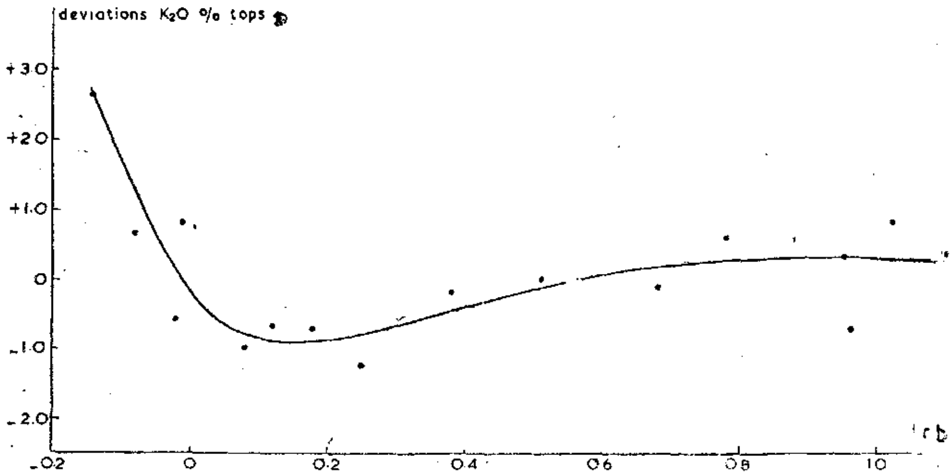

Fig. 3*a*

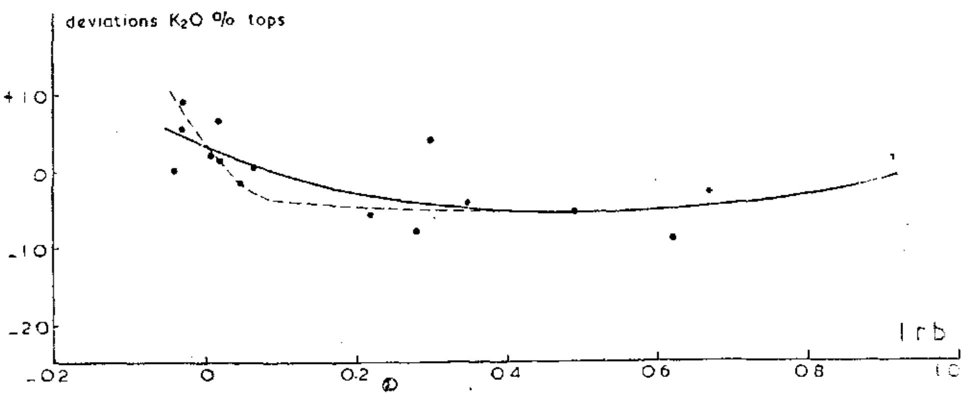

Fig. 3*b*

Fig. 3—Relation between lime status (lrb) and K_2O content of tops (measured as deviations from the average curve, fig. 2a) of Bevelander potatoes not dressed with potash after elimination of influence of content of particles $< 16\mu$ (average content $= 50\%$): (a) at K-value < 20, (b) ditto > 20.

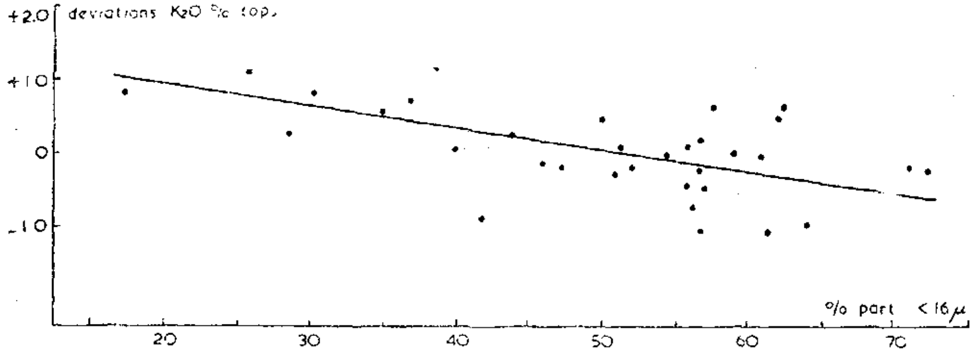

Fig. 4—Relation between content of particles < 16μ and K_2O content of potato tops.

The Eersteling variety, cultivated in the other trial-series, led in many respects to corresponding results. An important difference is, however, that this variety proves to be insensitive to a lime-potash antagonism, which is evident from fig. 5. The influence of the clay content was equal to that in the other experiment. In this case it appeared that tops with a higher nitrogen content also have a higher potash content (fig. 6). The explanation is probably that the crop was in different stages of development on the various fields and that a physiologically younger crop has both higher N and K_2O-content. By means of this relation the influence of the N-contents could be eliminated.

In interpreting the K-value, not only the corrected relation between the K-value and the K_2O content (as shown in fig. 2b), will be considered, but naturally also the influence of the clay content and, in the case of Bevelander, the influence of the lime status as well.

Fig. 4 shows that the K_2O content of the tops was higher by 0·3% when the clay content (at the same K-value) was lower by 10%. A difference of the same kind is also found on soils having the same

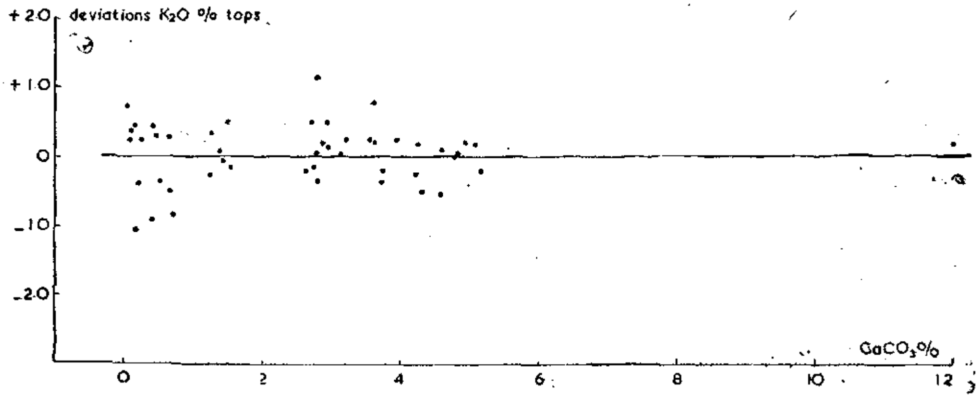

Fig. 5.—Relation between lime status ($CaCO_3$%) and K_2O content of tops of Eersteling potatoes not dressed with potash after elimination of influences of content of particles < 16μ and N-content of tops (average content of part.=25%, average N content=3·5%). Compare fig. 3a.

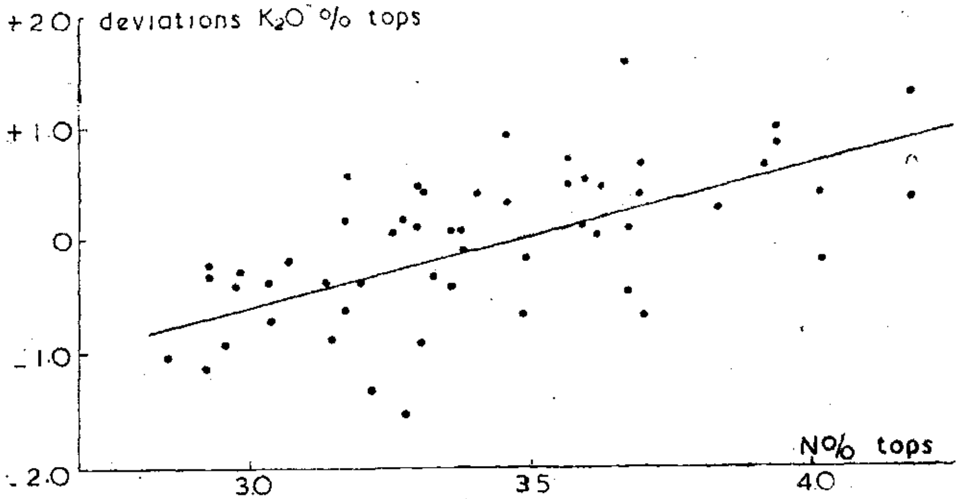

Fig. 6—Relation between N% and K_2O% of Eersteling tops.

clay content, but differing in the K-value by one unit (fig. 2b). So this means that a K-value on a lighter soil which is lower by one unit compared with a soil containing 10% more clay, must be evaluated equally.

It is more difficult to make allowance for the influence of the lime status. There is no great difference between calcareous soils. The greatest difference between lrb 0·1 and 1·0 expressed in the scale of the K-value definitely does not exceed 3 points. It is much more important to take the lime status into account with decalcified soils, where neglecting this factor would lead to an erroneous evaluation of the K-value.

A problem that has not yet been solved is whether the influence of the lime status on other crops is the same as that on the Bevelander potato. It is certain that most crops are susceptible to a lime-potash antagonism, but the fact that two varieties of one species differ so much in this respect, shows that further investigation is necessary.

The effect of the K-dressing was remarkably slight in 1950 (fig. 7). This was the reason that the increase in yield obtained by manurial treatment (expressed in the relative yield) was not satisfactorily related to the K-value, as in the two preceding years (compare figs. 8a and b). Even the heaviest dressing at a low K-value in 1950 was unable to supply the needs of the crop. This proves that soil potash (at any rate in some years) is of predominant importance.

The yields obtained on the various fields in this experiment also appear to be closely related to the K-value. There is no proof that this correlation is purely determined by the dependence of the yield on the availability of potash. There is always the possibility that the K-value is correlated with other unknown factors, which are the real causes of the differences in yield. However, in this instance in view of the reaction of the K_2O content of the tops, it is very likely that the differences in availability of potash are chiefly responsible for the differences in yield.

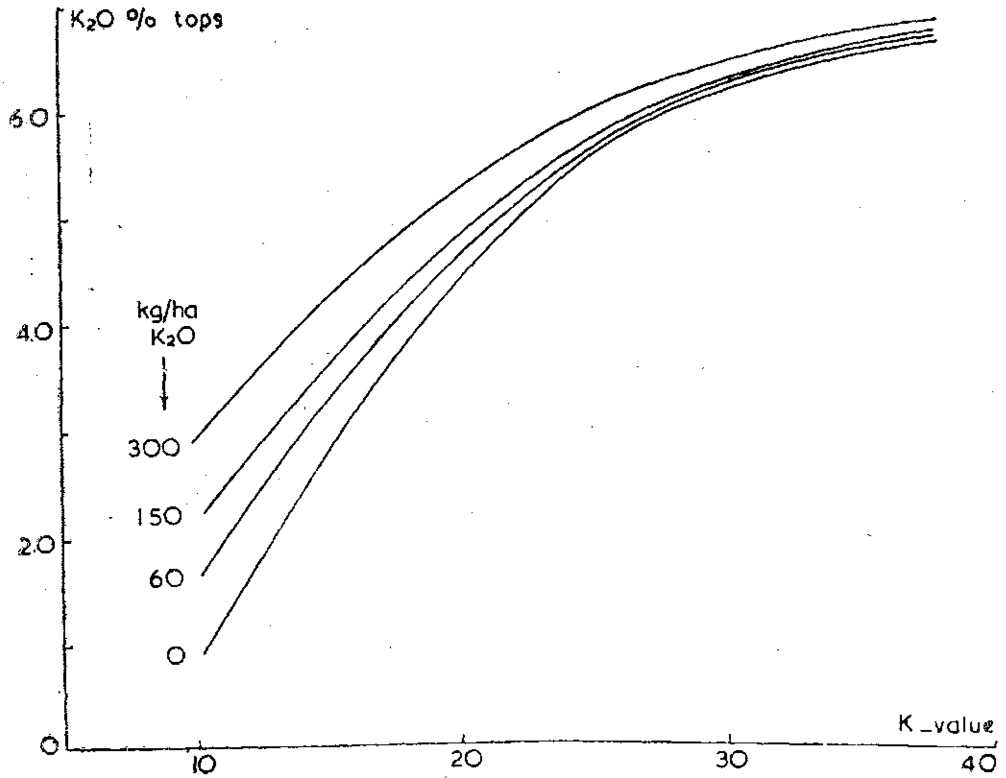

Fig. 7.—Relation between K-value of soil and $K_2O\%$ of Bevelander tops at differen K_2O dressings, after elimination of influences of lrb and content of particles $< 16\mu$ (average lrb = 0 and average content of part. = 50%).

Also this relation has been subjected to a further analysis, Fig. 10 shows the influence of the lime status. It is clearly evident (fig. 10a), that the Bevelander potato has produced the largest yield with an ample K-dressing on moderately calcareous soils. In case of potash deficiency (fig. 10b.) the effect of the lime status is less evident. We have seen that at the lrb-value showing the highest yield with an ample potash addition, the availability of potash is smallest (fig. 3a). It is clear, therefore, that an optimum lime status will only produce high yields, if ample availability of potash is ensured. It may, therefore, be concluded that in this fertile marine clay region appreciable increases in yield are possible (judging by Dutch standards!).

After this digression we finally like to show you the average result obtained in one of the polders (fig. 11) and this may be the basis for practical advice. An ample availability of potash in the soil was of great importance for the yield of tubers. The dry matter content (derived from under-water weights), however, shows a decrease at an increasing K-value. The result is that the extra amount of dry matter is much smaller and certainly does not justify an excessive increasing of the K-value. The effect of manurial treatment was slight

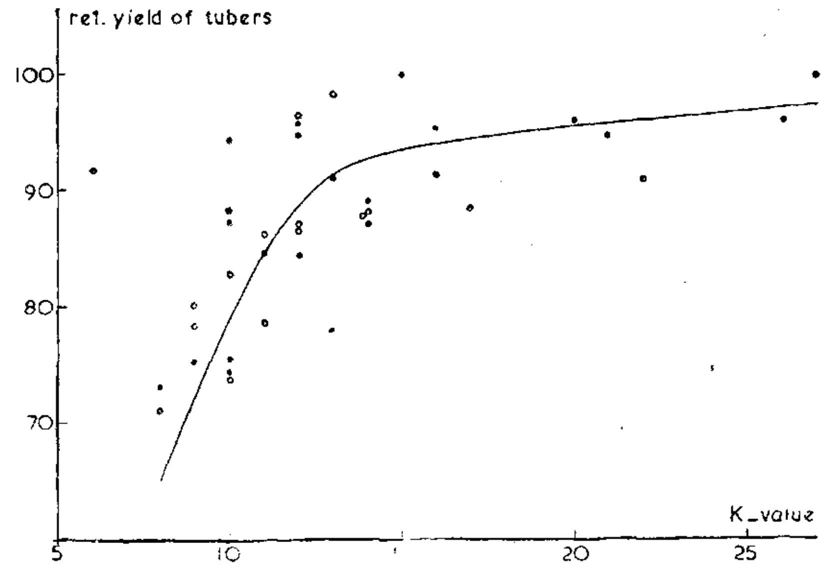

Fig. 8a

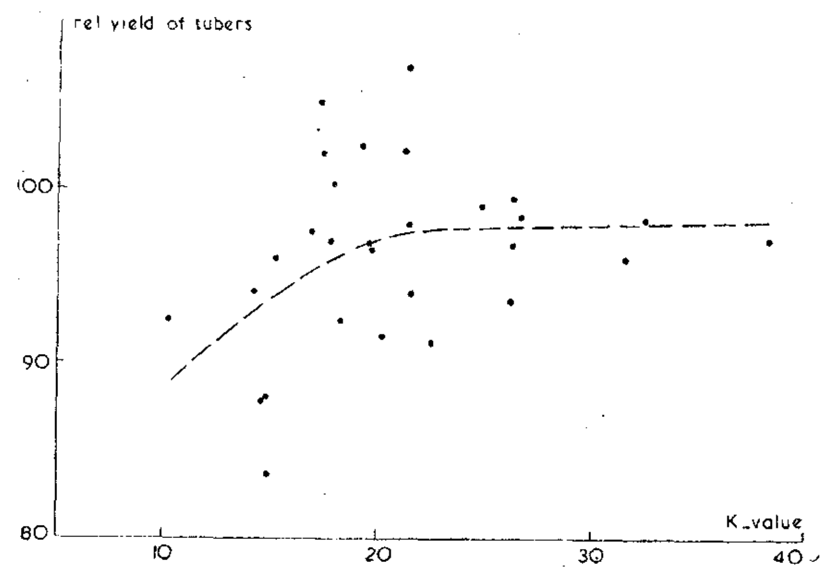

Fig. 8b

Fig. 8.—Relation between K-value of soil and relative yields of Bevelander tubers (a) in 1947 (dots) and 1949 (circlets), (b) in 1950.

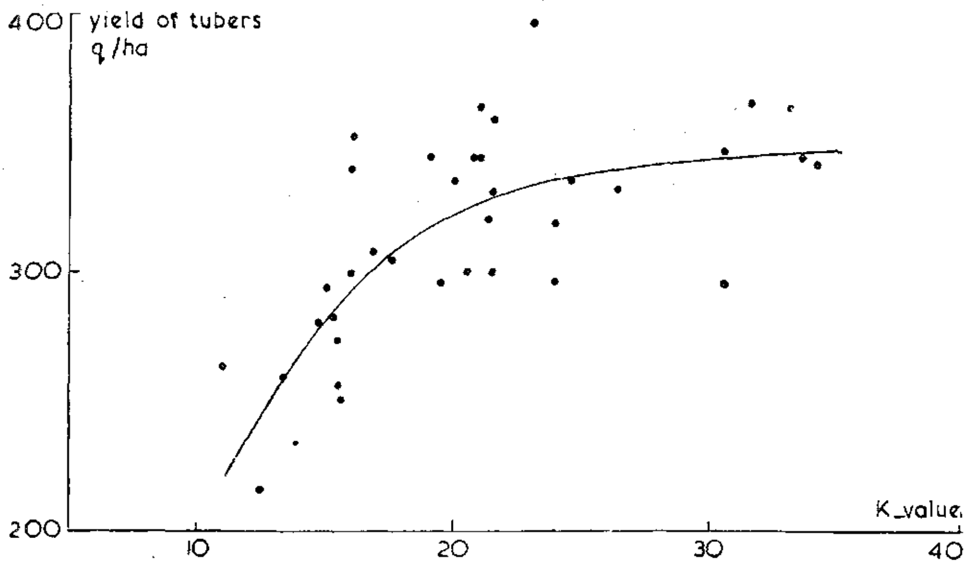

Fig. 9.—Relation between K-value of soil and tuber yields of Bevelander without K-treatment (in the Schermer polder) after elimination of influence of lrb (average lrb=0·08).

this year, but yet the economical value of the increase of the tuber yield at a K-value <20 exceeded the cost of the fertilizer.

It may be added that it is a problem of national economic significance whether the yield of tubers or the yield of dry matter is to be the criterion for determining the K-value. Also the quality of the tubers, which has not been discussed, must be considered. I just want to refer to this point to emphasize that although the evaluation of soil testing is essentially a scientific problem, economic and political considerations will ultimately be decisive for the evaluation of the figures.

It may not be superfluous to point out that this research, which describes the actual relation of facts but gives no causal explanation, is a great stimulus for the accomplishment of more fundamental investigations, which are thus closely connected to practical problems in farming. Also, the fact that these investigations tend to broaden our insight into the possibilities of manurial treatment, must be considered as important as the object proper, the evaluation of methods of soil testing.

This example may have shown that the possibilities of soil testing are numerous and that accurate calibration of the soil testing methods by means of field-trials is all the more justified according as practical farming has reached a higher level. I am convinced that the study and application of these possibilities in the various countries can lead to an appreciable increase in production and a more efficient use of fertilizers.

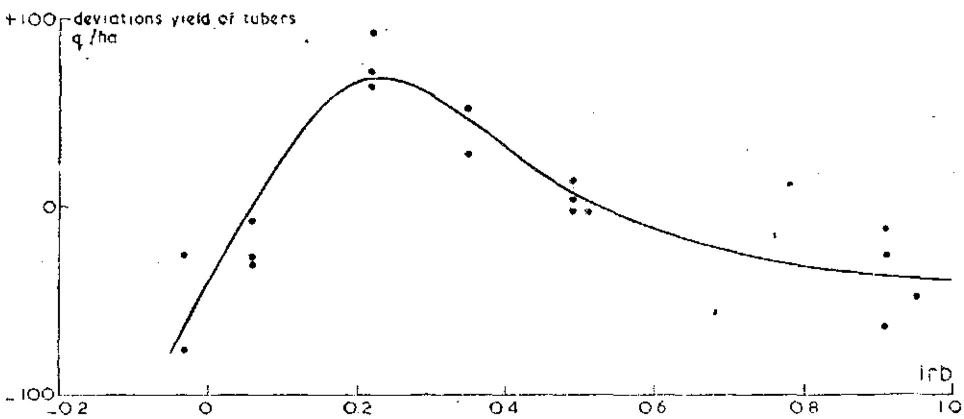

Fig. 10*a*

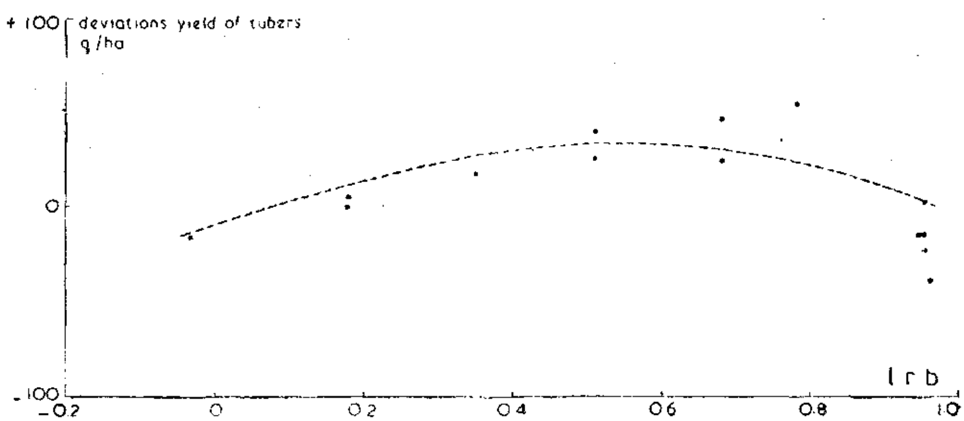

Fig. 10*b*

Fig. 10.—*Influence of lime status (lrb) on tuber yield of Bevelander: (a) K-value* > 20, *(b) ditto* < 20.

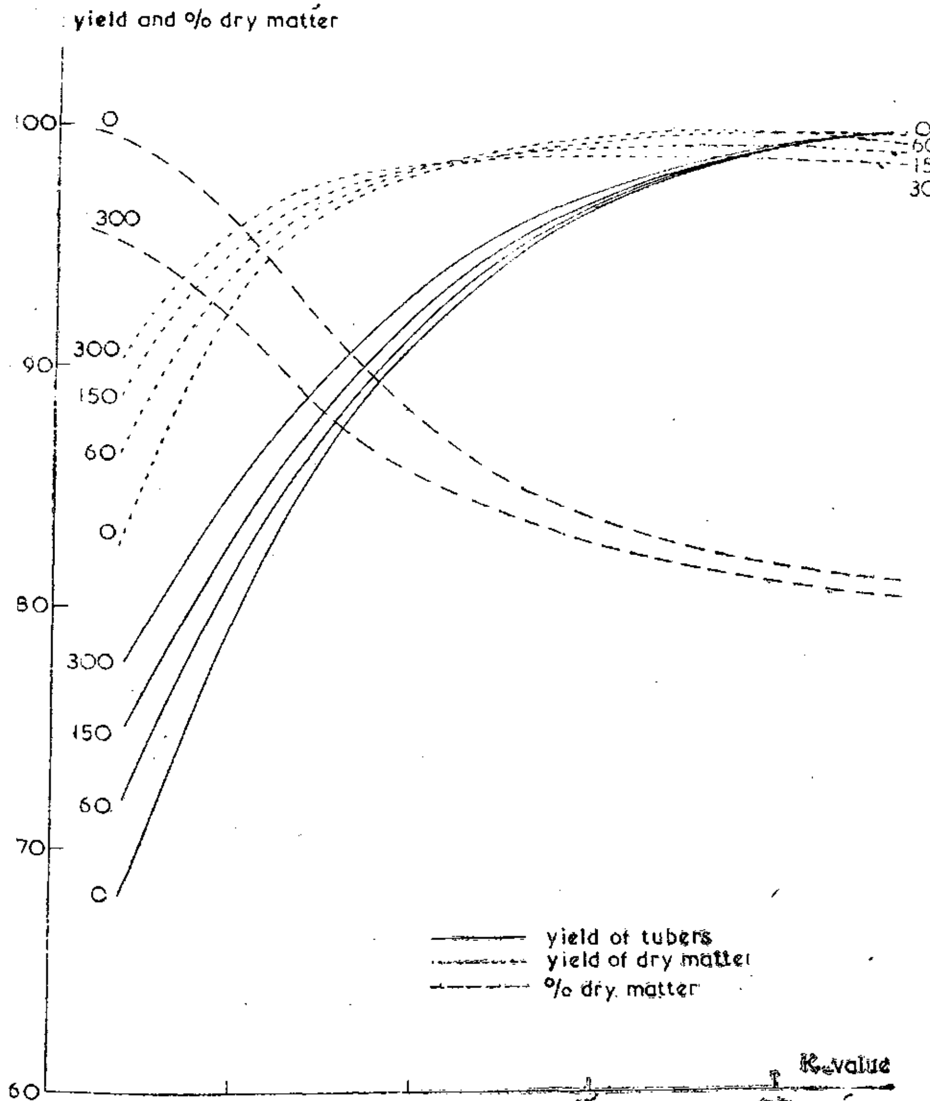

Fig. 11.—*Final result, showing average relation between K-value of soil and tuber yield of Bevelander, dry matter, and dry matter content with different K treatments.*