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CALIBRATION OF SOIL TEST METHODS FOR THE DETERMINATION OF PHOSPHATE AND POTASH STATUS

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INTRODUCTION

Intensive agriculture requires accurate advice on fertilizer requirements. If the advice is based on soil analyses much attention has to be paid to the agricultural "calibration" of these analyses.

The correlations between the analyses and the behaviour of the crops have to be established under normal farming conditions. Inevitably these conditions vary and calibration must therefore be performed on various soils and under various soil conditions. The following is an account of such calibration work carried out in the Netherlands.

METHODS

The general procedure in an investigation of this kind consists of the laying out of a series of field trials, on one soil group, all carrying the same crop. Such experiments are of one year's duration and are completed by further experiments which are continued for several years. The short-term experiments give the most direct information on the value of soil analyses. The long-term experiments make possible a comparison between the different crops of one rotation, and also the determination of changes in soil status under continued yearly fertilizer dressings of different magnitude.

Frequently the lay-out of the experiment is influenced by previous information. For example it is known that the availability of potash to the crop depends both on the potash status and on the lime status of the soil. Care should therefore be taken that these factors are correctly related in the investigation.

The trial fields must be selected in such a way that there is considerable variation in the potash values as well as in the other factors mentioned. The selection of the fields therefore requires preliminary soil analyses. If extensive soil analyses, in relation to agricultural practice, have previously been carried out on soils in the region where it is intended to establish the experiments, then data from such analyses may be a valuable help in selecting the trial fields.

The number of trial fields required for an adequate experiment depends on the number of factors which are expected to be operative, the extent of the correlations between these factors and the extent of their influence and interactions. Experience has taught us that at least ab. 30 trial fields are necessary for a limited area.

Care should be taken that the proportion of the various categories of trial fields is relatively equal, *i.e.* as far as possible equal numbers of fields which are poor, moderate, or rich in potash (and also poor or rich in lime, clay, or humus), should be selected even if some categories are rare in the particular region being investigated. An effort is also made to avoid correlations between the principal factors to be studied. If, for example, there is an evident correlation between potash and clay content, then an attempt is made to select the trial fields in such a way that both at high and low potash content there is ample variation in the other factor and vice versa. Another aim is to acquire an even distribution from a geographical point of view.

Fig. 1 shows an example in which the fields intended for experimentation have been selected from the results of previous soil analyses.The choice was made from the graphs obtained by plotting the potash value against both the lime content and clay content (particles less than 16 μ) and also the two latter against each other. If 3 factors are involved, the combinations selected to be included in an experiment will, therefore, have to be evenly distributed over a cube.

The lay-out of the trial fields can be simple. In the above-mentioned experiments concerning potash, each field contained 10 plots, each of 25 square metres. Four plots received no dresssing of potash; of the remainder, duplicate plots received 60, 150, 300 kg K_2O per ha as sulphate of potash. It is usual to express the yield obtained in the absence of added fertilizer as a percentage of the maximum yield which can be obtained on the same field under optimum conditions with regard to the factor examined. Experience has shown that percentage differences are more suitable than absolute ones. This relative yield is a measure of requirements for the nutrient in question. A disadvantage of this method is, however, that the highest yield obtained does not always agree with the theoretical maximum capacity of the soil. The effect of even large additions of the fertilizer often remains below this level. This discrepancy is especially prevalent on soils having high nutrient-immobilizing power and under low rainfall conditions, and also on grassland where the highest

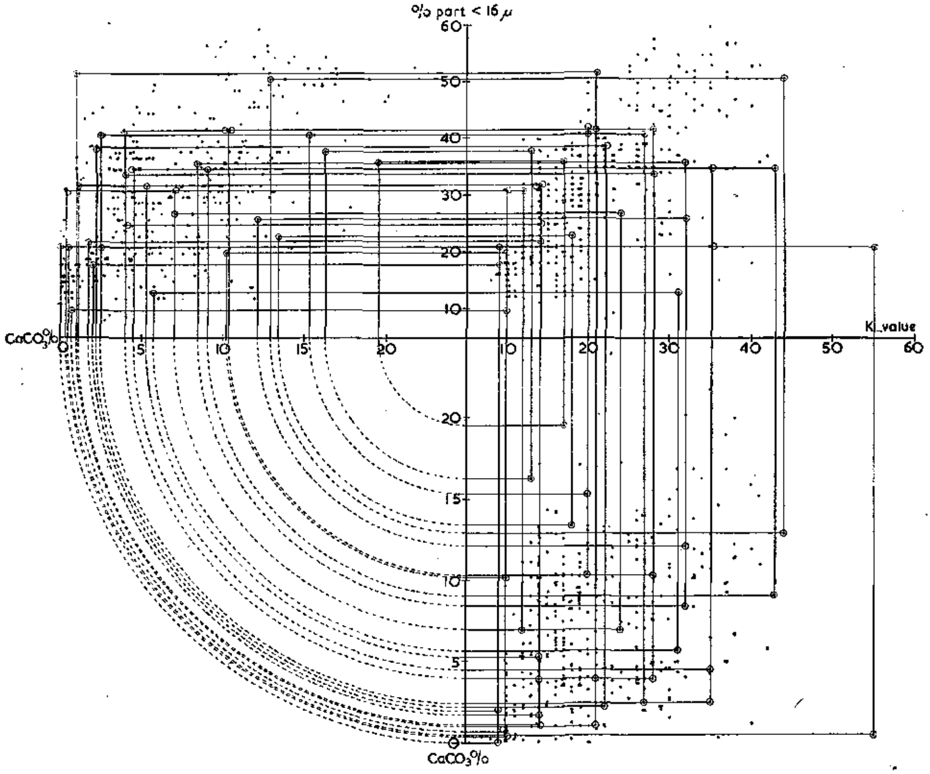

Fig. 1. Selection of trial fields from regional soil analyses after allowing for correlations between various factors and aiming at an even distribution. Dots represent the results of soil analyses. Circles represent selected trial fields.

possible productivity of the sward is not reached by a single fertilizer dressing. In addition, the determination of relatively small differences in yields demands a high level of accuracy in the experiments.

It is also very important that other properties of the crop which may be indicative of the availability of soil nutrients should be used for this purpose. The assessment of the content of a particular nutrient in plants, especially in the case of a rather young crop, from visible deficiency symptoms which can be expressed on an arbitrary scale 1–10 (see Ref. [29]), or from qualitative properties, such as starch content of potatoes or grain weight of cereals *etc.*, is often more accurate than the determination of differences of yields. Experience has shown that they are generally sensitive indicators of nutrient deficiency. A great advantage of the use of these indications is that they often already demonstrate deficiency symptoms even when the nutrient concerned still is available in a concentration sufficient for optimum yields. This results in many more data being available for statistical analysis. A disadvantage of the use of these properties of the crop is of course that before there can be application of the results verification with the yields is necessary.

The results of the field trials as measured by yields, chemical composition *etc.* are related to the nutrient status of the soils. Each field trial then gives one result in the experiment. The effect of some factors might be established by the aid of a linear regression analysis.

Experience shows, however, that the relations are mostly nonlinear. For this reason mathematical calculation is generally abandoned and a graphical treatment is adopted. It is possible to test statistically the reliability of the results obtained in this way (Ferrari [1], Ferrari and Sluijsmans [2]).

The fact that various properties of the crops can be used for calibration of the soil tests implies that much more simple experimental procedures may be followed in special cases. The possibility of field experimentation was limited to a great extent during World War II. Nevertheless an extensive investigation was conducted throughout the country by taking numerous crop and soil samples simultaneously from small plots of $^1/_4$ square metre each.

Other investigations which have contributed to the calibration of methods of soil analyses are the so-called regional soil fertility analyses. In this case experimental fields consisting of a number of plots are not laid out. Only single plots are used to which varied treatments are not applied, but of which the crop yield is determined and soil samples are taken. A statistical analysis of all the factors affecting the yield is then carried out; this is named *polyfactor analysis*. The relation between soil factors and yield and the interrelations of the former can be established (Ferrari [1]).

Evaluation of soil analyses by means of pot experiments may be useful in special cases. Experimental series performed in several clay soil regions in some years did not yield completely equivalent results. In an extensive pot experiment, soils from different regions have been studied simultaneously and under the same climatological and experimental conditions. Information as to whether differences in response to potash are due to differences between the soils has been obtained. In this way valuable information on the utility of soil analyses can be obtained. The calibration of analyses must, however, be restricted to the results from the field trials.

CORRELATION BETWEEN SOIL ANALYSIS AND CROP REACTION

A. *Short-term experiments*

1. Determination of the phosphate status of permanent grassland by soil analysis

The method in use in the Netherlands is to extract the soil sample (on grassland the 0–5 cm layer) with a 1% solution of citric acid. The *P-citr value* obtained from this treatment indicates the amount of P_2O_5 as mg per 100 gram of air-dry soil.

Series of experiments (20–22 experiments per series) were laid down in the years 1939–1941 on three soils in the neighbourhood of the town of Groningen. This investigation was repeated after the war on a much larger scale throughout the country. During 1947 and 1948, 330 field trials were laid down with the aid of the Agricultural Advisory Service. These experiments were divided into series, according to soil group and geographical situation. The main groups of soils investigated were peat, marine clay, river clay, loess and sand soils respectively.

The field trials consisted of 12 plots, each 5 × 5 metres. Four of these plots did not receive any dressing with phosphate, the others were dressed in duplicate with 20, 50, 90 and 140 kg P_2O_5 per ha. (in the form of double superphosphate). Nitrogen was added as ammonium nitrate limestone (50 kg N per ha) and potash in different amounts according to the need of the fields. Only one mowing was harvested.

The average yields of the plots without phosphate dressing as a percentage of the maximum yield obtained from plots with adequate fertilizer, on the same field, have been used as a measure of the need for application of phosphate.

It is assumed here that the yield of a field with a low phosphate status will, when adequately dressed with phosphate, be of the same order as that of fields having a much higher phosphate level, so that the yields in both cases can then be put at 100. This is certainly not true if fields highly deficient in phosphate are included in the investigation. The present investigation has, however, been restricted to fields in normal condition. It could be proved that, under such conditions the assumption was justified.

The P_2O_5 content of the dry matter of grass grown on plots receiving no phosphate dressing has been used for the same purpose. However, a correction had to be made for the varying N-contents of the grass of the different field-trials. By means of the definite ratio observed between the N and the P_2O_5 contents of the grass, it was possible to adjust the P_2O_5 contents to those for grass having an equal N-content. In consequence, variations arising from differing stages of physiological development and different species composition are largely eliminated. These adjusted values for the P_2O_5 content of the grass proved to be a sensitive measure of the availability of soil phosphorus.

Some examples may give a better picture of the results obtained.

A series of 33 experiments was performed in 1947 on a clay soil in the northern and north-western part of the country and another series of 29 field-trials in 1948 in the western and south-western part. Relative yields in both series have been plotted against P-citr values in Fig. 2. The results are very satisfactory and indicate that in both years the yield progressively decreased where the P-citr value fell below 40. With P-citr values higher than 40, only small increases were observed when additional phosphate was added.

In another case concerning a series of 40 field trials made in 1947 on peaty grassland the result was less satisfactory (Fig. 3). The P_2O_5 contents of the dry matter of the grass were, however, much better

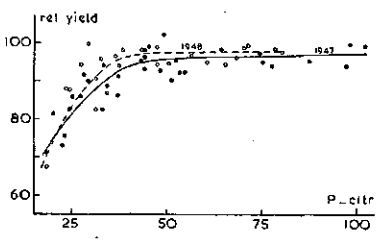

Fig. 2

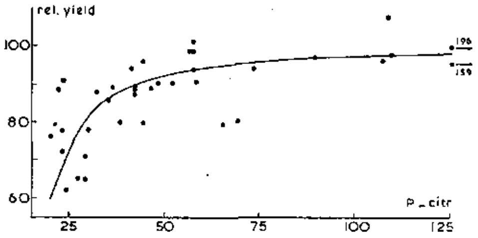

Fig. 3

Fig. 2. Relation between P-citr value and relative yields for marine clay soils for 1947 (dots) and 1948 (circles).

Fig. 3. Relation between P-citr value and relative yields on peaty soil (1947).

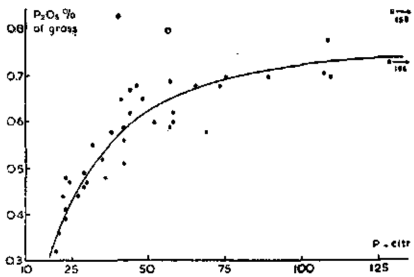

Fig. 4

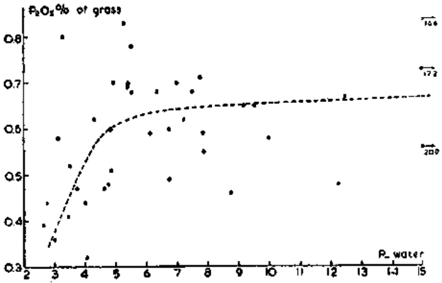

fig. 5

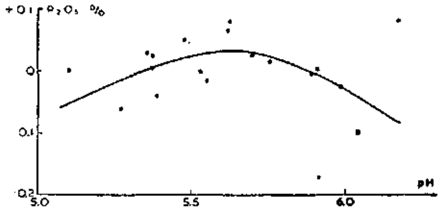

Fig. 6

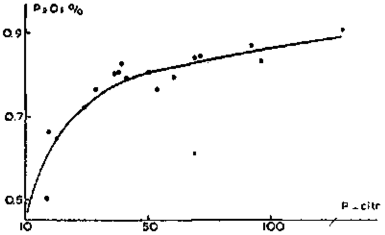

Fig. 7

Fig. 4. Relation between P-citr value and P_2O_5 content of the dry matter of grass (corrected to $N = 1.8\%$) grown on peaty soil not dressed with phosphate (1947).

Fig. 5. Values for the P_2O_5 contents of the dry matter of grass as used in Figure 4 plotted against *P-water* (soil sample extracted with warm water, 50°C).

Fig. 6. Relation between pH of the soil and P_2O_5 content of grass (positive or negative differences from the average content for sandy soil, after elimination of the influence of variations in P-citr value and differing N-contents of the grass (1941).

Fig. 7. Relation between P-citr value and P_2O_5 content of grass grown on sandy soil, after elimination of the influence of differing soil pH and variation in the N-content of the grass (1941).

correlated with the P-citr values (after elimination of the variations due to different N-contents) thereby indicating that the less pronounced correlation of relative yields was not due to a defect in the method of soil analysis (Fig. 4).

In some cases the correlation could be improved by taking other factors into account. The scatter of the points observed in some graphs proved to be partly due to other factors such as pH of the soil and humus content. An example of the first is given by an experimental series for 1941 on sandy soil. In this case the positive or negative difference between the actual values for P_2O_5 content of the grass after elimination of the variations due to difference in N-content and the values appropriate to the corresponding P-citr values according to the smooth curve through all the points have been plotted against pH (Fig. 6). For this procedure to be valid it is necessary that there should be no correlation between P-citr and pH. The positive deviations of P_2O_5 contents occurred at moderate pH values and negative deviations at relatively low and high pH. A similar relationship has been noted repeatedly for different kinds of soil. The correlation of P_2O_5 content of grass with P-citr value in this series is shown in Fig. 7.

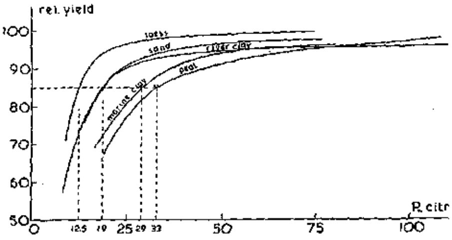

Fig. 8

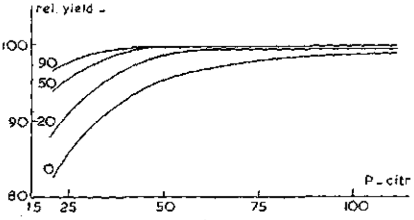

Fig. 9

Fig. 8. Relations between the averaged values for varying numbers of years, for P-citr value and relative yields as determined for marine (3 years) and river (1 year) clay soils, loess soil (2 years), peaty soil (2 years) and sandy soil (3 years).

Fig. 9. Relation between P-citr value and relative yields at different levels of phosphate application (kg P_2O_5 per ha) for sandy soil (1941).

These and similar results obtained for other series in different years have been averaged (Fig. 8). It is clear from this that the agronomical value of P-citr values differs from soil to soil. A value of 33 on peaty soil proves to be equivalent to 19 on river clay and sandy soil, to 29 on marine clay and to 12.5 on loess.

In addition to such considerations fertilizer advice is based on results derived from the effects obtained with different amounts of P-dressing. The correlation between P-citr and relative yields for different P-dressings, obtained in the above mentioned series of field trials on sandy soil in 1941, is shown in Fig. 9.

As the effect of small additions of phosphate is relatively large by comparison with the effect of differences in P-citr value, it is concluded that the effect of freshly added fertilizer phosphorus is much greater than the effect of an equal amount of soil phosphorus.

As a result, the following advisory scheme (Table I) has been derived from the experimental results. It has been put forward in consultation with grassland specialists. In some ways the work is incomplete as it only relates to results obtained for the first mowing of grasslands. The reaction of grassland to phosphorus manuring at mid-summer is certainly less than that in spring.

TABLE I

Advice regarding phosphate manuring of grassland based on the P-citr values obtained for grassland mown once and used for grazing afterwards

P-citr value					P_2O_5 dressing in kg/ha
Peaty soil	Marine clay	River clay	Sandy soil	Loess	
<36	<31	<21	<21	<16	150—100
36—55	31—45	21—35	21—35	16—25	80—60
56—80	46—65	36—60	36—60	26—45	50—40
81—120	66—100	61—90	61—90	46—65	30—20
>120	>100	>90	>90	>65	0

With other cropping treatments the following deviations from this scheme are recommended:

1) When continually used for grazing 20 kg P_2O_5 per ha less dressing each year and with very intensive use only 10 kg per ha less each year.

2) When mown twice and used for grazing afterwards an additional supply of 30 kg P_2O_5 per ha and with very intensive use an additional supply of 40 kg per ha.

3) When mown exclusively (*e.g.* for grass drying) an additional supply of 110 kg P_2O_5 per ha yearly.

It is interesting to note that another method, in which the content of P_2O_5 soluble in water at 50°C is determined, adopted in the Netherlands, proved to be impracticable in some cases. Fig. 5 shows the same P_2O_5 contents of the dry matter of grass as presented in Fig. 4 plotted against this value. Nevertheless this method was useful in other cases. A special disadvantage of this method is the large variability over a period of time.

It has been mentioned that simplified experiments were performed during the war. Samples of soils and plants taken simultaneously from the same plot yielded valuable results. Fig. 10 shows the relation between the P-citr value and the P_2O_5 content of grass from grassland on river clay soils in the central region of the country. Fig. 11 similarly shows the relations between the P-citr value and the P_2O_5 content of young rye grown on river clay soil.

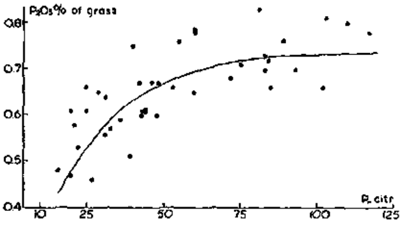

Fig. 10

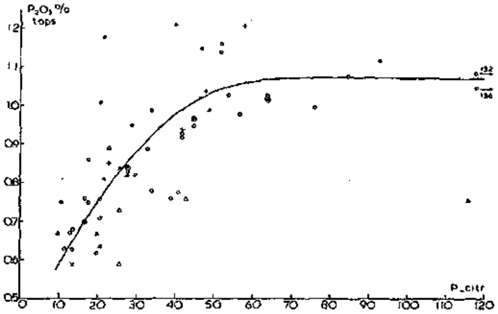

Fig 11

Fig. 10. Relation between P-citr value and P_2O_5 content of grass grown on marine clay soils (1943) using the sampling method, without corrections for interactions of other factors.

Fig. 11. Relation between P-citr value and P_2O_5 content of young rye grown on river clay soil (1943) using the sampling method, without corrections for interactions with other factors.

2. Determination of the potash status of arable land from soil analyses

The discussion of the problem is restricted to investigations carried out on clay soils. It will be shown that the problem is rather complicated but that, nevertheless, useful results have been obtained.

Experiments on four series of experimental fields carrying potatoes were performed in different years and in different parts of the marine clay region. The setting up of such an investigation has been discussed before (Fig. 1). The results from such a series of experiments will be discussed below.

The relation was studied between the *K-value* * and the increases in yields of tubers resulting from potash dressings the K_2O-contents

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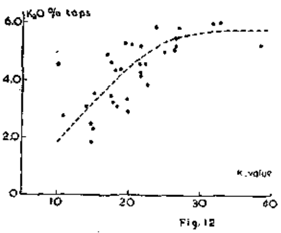
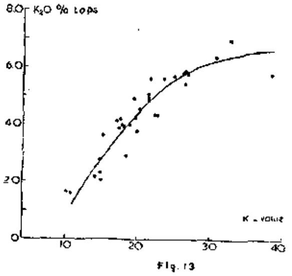
* This *K-value* indicates the amount of exchangeable K_2O extracted with 0.1 *N* HCL as mg per 100 g of air-dry soil.

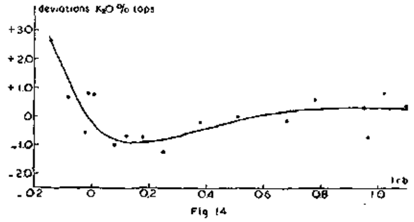
of tops of fairly young plants and of tubers under-water-weights of tubers, actual yields and in some cases by vigour scoring in addition.

The relation between the K-value and the K_2O-contents of the tops of the potato plants generally gave the most obvious indications. The results obtained have been checked,however, by the other observations and have been related to them.

In agreement with the results of former investigations the availability of potash proved to be dependent on three soil factors, namely the K-value, the lime status, and the clay content (particles $< 16\,\mu$). The effect of each of these factors has been determined in turn, those factors having the largest effects being analysed first. According







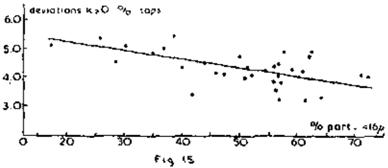


Fig. 12. Relation between K-value of the soil and the K_2O content of potato tops for marine clay soil (1950).

Fig. 13. Relation between the K-value of the soil and the K_2O content of potato tops after elimination of the influence of variations in lime status and content of particles $< 16\,\mu$ for marine clay soil (1950).

Fig. 14. Relation, for a low K-value <20, between the lime status (lrb) and K_2O content of potato tops (grown on soil not dressed with potash) measured as deviations of the values from the average curve after elimination of the influence of variation in the content of particles $< 16\,\mu$ (average content $= 50\%$).

Fig. 15. Relation between content of particles $< 16\,\mu$ and K_2O content of potato tops, as deviations from the mean, after the influence of variation in K-value and lime status have been eliminated.

to this method, called polyfactor analysis, the influence of the K-value (being the most important factor according to preliminary determinations of correlations) has been provisionally determined by a free-hand curve (Fig. 12).

This having been done, the influence of a second factor is determined. The influence of this factor is also determined graphically after the influence of the K-value has been eliminated. In the instance in question this was done by plotting the ordinate distances of the points from the curve in Fig. 12 against the corresponding values for the second factor. A point above the curve of averages indicates that the uptake was better than the average value, a point below it indicates the reverse.

Interactions between the factors are determined as far as possible. If the number of determinations is sufficient, they are divided into two or more groups of different K-values and the procedure is followed independently within these groups. 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 depending on whether 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 then be eliminated. The influence of the third factor is then determined in the same manner. When this has been determined, further corrections can be made. The adjusted K_2O-contents have been plotted against the K-value in Fig. 13. Moreover, it is possible to determine the influence of the second factor more accurately after the influence of the third factor *etc.* has been eliminated.

The relation between the lime status (here indicated as *lrb-value* *) and the deviations of the points from the average curve (Fig. 12) is demonstrated in Fig. 14 for a low K-value (< 20). The influence

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* pH is not very suitable as an accurate indicator of differences in the lime status of calcareous soils because soils having varying contents of $CaCO_3$ show only slight differences in pH. On the other hand the $CaCO_3$ content is zero in the case of decalcified soils. Visser introduced the lrb-value (logarithm relative base content, lrb $= \log (S + 20 \times CaCO_3\%)/T$. The numerator is determined by measuring the degree of neutralization of added 0.1 *N* HCl; T = sorption in equilibrium with a surplus of $CaCO_3$) which can be determined in either case and allows the decalcified and calcareous soils to be considered on a single scale. In the case of soils with a neutral reaction but from which $CaCO_3$ is almost absent, lrb = 0. Decalcified soils give negative values whilst those containing $CaCO_3$ give positive values. In the case of a soil containing 1% $CaCO_3$ lrb = *ca* 0.2; whilst in the case of a soil containing 10% $CaCO_3$; lrb = *ca* 1.0.

of the third factor (content of particles less than 16 μ) has also been eliminated in this case.

The influence of the lime status is different. At a low K-value the K_2O-content appears to have been strongly affected by this factor. High K_2O contents have occurred on decalcified soils and low contents on moderately calcareous soils. At higher lrb-values there is an increase in K_2O content. Such a complex relation has frequently occurred in other series of potash experiments. There is little doubt that with increasing lrb values, decreasing K_2O contents are to be attributed to lime-potash antagonism. It is not so easy to give an explanation of an increase in K_2O content in the case of higher lrb values.

In the case of higher K-values, where potash no more acts as a primary factor the influence of the lime status was found to be less pronounced.

The influence of clay content is shown in Fig. 15. It was impossible to demonstrate an interaction for this factor and therefore all the determinations have been used. In this figure the influences of the K-value and the lrb-value have been eliminated. Soils with a higher clay content have yielded tops having lower K_2O contents than was the case with lighter soils.

There was no very distinct correlation between the K-values of the soils and relative yields in this series. The cause of this was probably associated with the fact that even the highest dressing (300 kg K_2O per ha) did not fully satisfy the requirements of the crop.

This difficulty in using relative yields as an index (this method has also been used by others) is clearly shown in the case of a river clay soil in an investigation by Ferrari[1]. He compared the use of relative yields with the use of absolute yields as tests of the K-value method (Figs. 16 and 17). It is clearly shown that a heavy dressing with 300 kg K_2O per ha did not suffice to satisfy the needs of the crop on this highly deficient soil. The use of relative yields (yield obtained without K-dressing as a percentage of the highest yield obtained with K-dressing on the trial plot)gives an erroneous picture of the real needs.

Attention may also be drawn to the possibilities of using mere visual observations of the crop. In one series simultaneous vigour scorings of the plots of all field trials were made on a scale of 1–10. These numbers have been reduced, in a similar way, to relative vigour scorings by expressing the vigour score given to the crop not dressed with potash as a percentage of the score awarded to the crop receiving the maximum dressing on the same experimental field. These relative values show a good correlation which the K-values of the soil (Fig. 18); not differing very much from the correlation between the K-values and relative yields observed in the same experimental series.

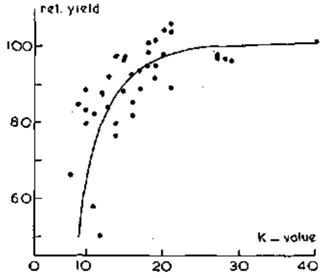

Fig. 16

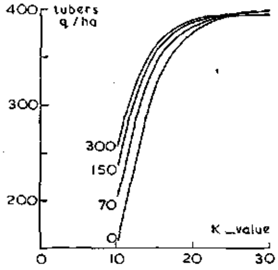

Fig. 17

Fig. 16. Relation between K-value of the soil and the relative yields of potatoes obtained in the absence of potash dressing and expressed as a percentage of the yields from the corresponding K(150) plots for river clay soil (according to Ferrari[1]).

Fig. 17. Relation between K-value of soil and yield of potatoes at 4 levels of potash application (kg K_2O per ha) for river clay soil (according to Ferrari[1]).

The investigations described above have provided the basis for the advisory scheme for potash dressings. The results permit the assessment of the relation between the influence on the reaction of the crop of a difference of one unit of the clay content scale and of one unit of the scale used for the indication of the lime status, to the scale of the K-value. With the aid of these relation the K-value is corrected to a value valid for soils with moderate clay and lime content.

Serious difficulties have still to be overcome. The investigations conducted in different years and regions do not always give similar results. The correlations with lime status and clay content especially do not agree in all cases. Nor do different crops behave similarly. River clay soils, showing less response to potash dressing owing to stronger fixation of potash by these soils, behave differently as compared with marine soils. Since only statistical relations have been studied, these differences are not surprising. The real causal relations are still obscure.

For practical reasons it will be impossible to continue these investigations indefinitely. They are expensive and take much energy. From a scientific point of view the problem is, however, not yet solved. Differences between the results for series of experiments in different areas or different years require further explanation. A pot experiment has therefore been carried out to investigate soils of different origin under comparable conditions. Oats, potatoes and beet were grown in succession on 123 samples of soil taken from different clay regions. These plants were used in view of their differing response to potash dressings and potash-lime antagonism. The crops were grown with (1 g K_2O per pot of 20 cm diametre) and without potash dressing and harvested at a rather young stage of development. The correlation between soil potash and the potash content of the potato plants is very good. This correlation is not affected by the origin of the soil (Fig. 19). However, one particular difference was noted between river and marine soils. Whilst the

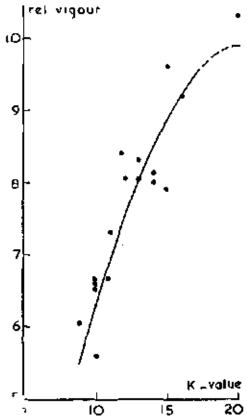

Fig.18

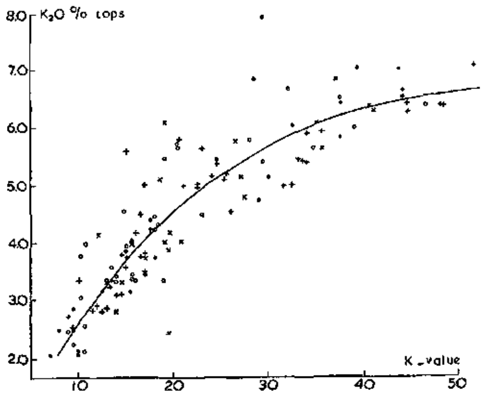

Fig.19

Fig. 18. Relation between K-value of soil and relative vigour of the potato crop, after elimination of influence of variation in lime status ($CaCO_3 = 1\%$) and content of particles $< 16\ \mu$ (35%) for marine clay soil (1949).

Fig. 19. Relation between K-value of soil and K_2O content of potato tops in a pot experiment with clay soils of different origin (without corrections for interactions of the other factors).

potash dressing sufficed to satisfy the requirements of the plants completely in the case of the latter it did not do so in the case of the river soils. Investigations are continuing to elucidate the nature of the differences between these two soils.

It is clear that the results obtained in pot experiments are not applicable to field conditions. Correlations with lime status were, however, not different from those observed under field conditions.

3. Determination of the potash status of grassland from soil analyses

Until recently the K-value (HCl) method was also applied to grassland on clayey and peaty soils. Field trials similar to those described above for phosphate have been performed. The calibration of this value proved, however, to be impossible without considering the influence of humus content. This is clearly shown by the relations observed between K-value of river clay soils having different humus contents and the K_2O content of the dry matter of the grass crops grown on these soils (Fig. 20).

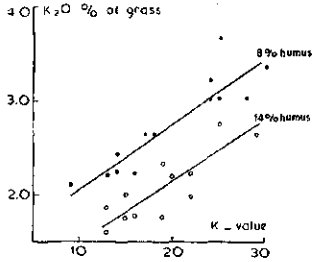

Fig. 20

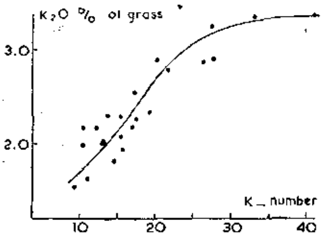

Fig. 21

Fig. 20. Relation between K-value of soil and K_2O content of grass (without corrections for variations in N-content) at 2 different levels of humus content for river clay soils not dressed with potash (1948). The data obtained for soils containing 3.5–10.6% of humus have been adjusted to correspond to a humus content of 8%; those with 11.2–19.1% had been adjusted to correspond to a humus content of 14%.

Fig. 21. The same data as in Fig. 20 plotted against *K-number* instead of K-value).

The method used in the case of sandy soils * also proved to give

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* According to this method an amount of soil containing 6.25 g of humus is extracted with 300 ml 0.1 *N* HCl. The ratio of potash released to humus content, multiplied by a certain factor, is determined. (This so-called *K-number* can also be derived from the K-value and the humus content by means of an empirical formula).

quite satisfactory results with this type of soil. The results used in Fig. 20 have been plotted against *K-number* in Fig. 21. It is clear from this that the method using K-number is preferable to that in which K-value is used since advice can be given without introducing a correction for humus content. In this case the influence of clay content was negligible, so that a test has been obtained which is very suitable for application to agricultural practice.

B. *Long-term experiments*

The picture obtained from field trials of one years duration is completed by experiments which are continued for several years. Such experiments were laid down on the main soil types throughout the country.

1. Phosphate experiments on arable land

These experiments are meant to give information about changes in phosphate status following the application of different phosphate dressings. The results are very interesting as it can be shown that the phosphate status on sandy and reclaimed moor soils tends to reach a state of equilibrium when there are constant yearly additions of phosphate (some examples in Fig. 22). It may be concluded that losses through leaching are much more important, in the case of ample dressings, than was hitherto considered to be the case. On clay soils, on the other hand, this phenomenon has not been observed. With ample phosphate dressings the P-citr values increase proportionally with time.

With moderate dressings changes in phosphate status take place relatively slowly, thereby indicating that the determination of phosphate status from soil analyses gives reliable indications which are valid for several years.

These long-term experiments may also give information about the value of soil analysis. It is difficult, however, to estimate the phosphate deficiency of any particular field as different crops with unequal requirements have been grown in different years. This difficulty has been partly overcome by evaluating the requirements of crops in the following way. The relation between relative yields (*i.e.* yields obtained in the absence of added phosphate expressed as percentages of the yields obtained with the highest phosphate dressing) for different crops grown in successive years is determined.

The results obtained for potato and rye on sandy soil are presented in Fig. 23. The responses of crops to added phosphate vary considerably in different years. Nevertheless a clear picture is obtained. It was also shown that the requirements of potatoes and beet are almost identical. The response of other crops has now been converted into that for beet and potatoes. In this way the average response to phosphate with these two crops in each field trial has been determined. These mean relative yields have been plotted against the mean P-citr values obtained for the plots receiving no phosphate dressing. The result obtained on clay soils (Fig. 24) is rather illuminating.

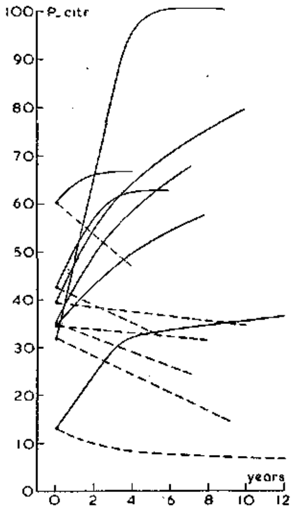

Fig. 22

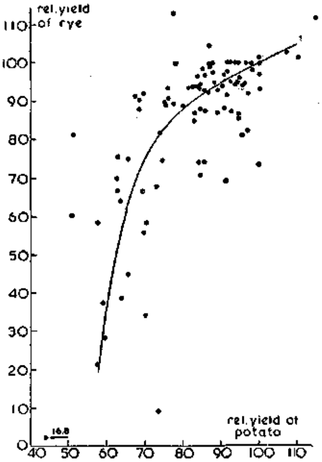

Fig. 23

Fig. 22. Variations in the phosphate status of arable land (sandy reclaimed moor) following heavy dressings (200 kg P_2O_5 per ha yearly) – continuous line curves, and in the absence of phosphate dressings – broken line curves; for a number of different experimental plots.

Fig. 23. Relation between relative yields of rye and potatoes obtained in successive years in the absence of phosphate dressing.

Two experiments on loess soil gave results deviating from those on clay soil. Similarly it has been observed on grassland (p. 112, Fig. 8) that the P-citr value for this soil differs considerably from the value obtained in the case of other soils.

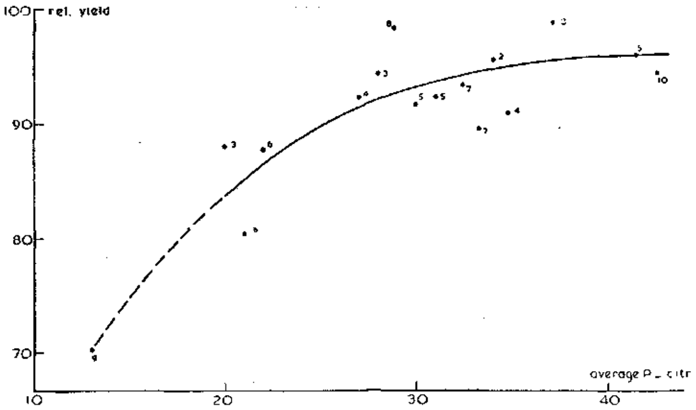

Fig. 24. Relation between P-citr values for clay soil and mean relative yield, in the absence of phosphate dressing, related to the response of beet and potato (found to be almost identical). The numbers associated with the various points indicate the number of the years of the experiments.

2. Potash experiments on arable land

It is less useful to analyse soil for potash than for phosphate. One of the reasons for this lies in the more difficult calibration of the analysis in relation to other factors affecting the availability of potash. Another reason concerns the greater variability of the results, especially on sandy and light clayey soils. Yearly fluctuations are much larger since the store of available potash is smaller and more readily changed by addition of fertilizer, absorption by plants and leaching.

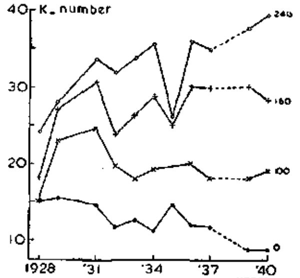

Fig. 25

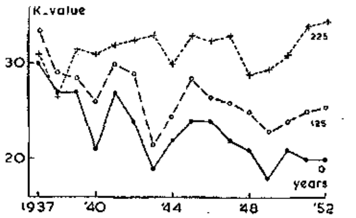

Fig. 26

Fig. 25. Variation in the K-number over a trial-field (OO 51) on sandy soil, for different dressings of potash (kg K_2O per ha).

Fig. 26. Variations in the K-value over a trial field (ZHE 341) on marine clay soil.

Fig. 25 gives an example of the variations in the potash number on a sandy soil for different potash dressings under a rotation of potatoes and rye. Considerable fluctuations occurred. A certain level of equilibrium is reached after a relatively short time. Excess potash is leached down into the subsoil. This is especially the case if the potash status has been raised to a high level by heavy dressings, and potash dressings are then subsequently omitted.

Another example concerning a clay soil containing 50% of particles $< 16\ \mu$ (Fig. 26) shows that in this case also fluctuations occur and that no considerable differences in soil potash level arise, despite large differences in the amounts of potash applied. The value of the test is restricted by this drawback. Therefore, advice on the basis of the potash test has a more limited value. Only for the first year can exact advice be given. The advice for the following years will be vague. The usefulness of the test rests primarily on the fact that it permits a critical comparison of the potash status of different plots of the same farm and comparisons between farms and regions.

The above examples may suffice to give an impression of the work done in this field in the Netherlands. For more extensive information the reader is referred to previous papers on the subject in Dutch [1] [3] [4] [5] [6] [7] [8] [9] [10]. Summaries and charts, with information in English, have been included in most cases.

SUMMARY

The practical value of soil analyses depends to a large extent on the accuracy of the calibration of the tests under field conditions. Examples are given to illustrate the procedure followed in work performed in the Netherlands along these lines.

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