The Organisation and Rationalisation of Soil Analysis. Project No.156.OEEC, Paris 1956, pp.165-176.

CALIBRATION OF SOIL TESTING IN THE NETHERLANDS BY MEANS OF FIELD EXPERIMENTS

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Professor Bondorff has given an excellent survey of the requirements which soil testing has to fulfil. I can add very little to this.

My lecture can tie on to the experimental part of his paper. I intend to describe the way in which we have tried to solve similar problems in the Netherlands. The use of fertilisers is considerable in this country so that an economical use is wanted. Much attention has therefore been paid to the calibration of the tests.

As Professor Bondorff pointed out, the values obtained are no more than mere functions of the available plant nutrient. The results will never be more than a sign and it will be the task of the agriculturist to evaluate this sign under farming conditions.

Experimentation in the field and that in the laboratory was linked up very early in the Netherlands. It was observed in the field that there is a close relation between liming conditions and yield. Liming conditions could be determined in the laboratory and till the present time the pH is used as a sign, which may be of use to ascertain optimum growth conditions.

Historically, these investigations originated half a century ago by the observation of a soil-borne plant disease which was later diagnosed as manganese deficiency. The disease occurred on soils which were overlimed. Another disease was observed especially occurring on the acid soils, at present known as magnesium deficiency. It proved to be possible to distinguish these soils by means of a determination of the soil reaction. Thus the pH was used as an indication for the occurrence of manganese and magnesium deficiency, though this was not realised at the time. On the experimental fields with increasing amounts of lime it appeared that a correlation between pH and yield was also found under less extreme conditions where no deficiency symptoms occurred. In this region the pH is still used as a sign, though it must be admitted that we know indeed little about the real causal relations.

The important thing is to evaluate the methods of soil testing under practical farming conditions. It will be clear that a small number of experimental fields will not be sufficient for this purpose. Agriculture has multiple aspects : many soil types, many soil properties, many crops, etc.

The evaluation must be done over the whole scale in which the soil factors vary. Soils with low, medium and high contents of the nutrient concerned must be used for field-trials. This, however, is not sufficient. Other factors which may be influential must also be taken into account and a wide variation of these factors will be necessary too. It is clear that very large numbers of experiments would be required for this purpose. It will, however, be wise to restrict the investigation to what is possible. For practical reasons it is suitable to restrict the size of the region and the variation of the soil type under investigation, to perform the experiments simultaneously and to use one single crop, which is sensitive to the soil factor studied. Of course, the crop must be important from an economic point of view.

The investigation will be facilitated if previous information is available as to the factors which must especially be considered. Preceding experience has taught us, for instance, that the availability of soil potash not only depends on the amount of exchangeable potash, but on the lime level and the clay content of the soil as well. Care should be taken that at any rate these factors are correctly implicated in the investigation. The number of trial-fields 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. We have found, however, that the extent of the investigation can often be restricted to some tens of trial-fields.

The method described is a simplified application of the method of poly-factor analysis which aims at a complete statistical analysis of all factors determining the yield.

The selection of plots suitable to the layout of a trial-field requires therefore a preliminary soil testing on a relatively large scale.

Figure 1 shows an example in which the fields intended for experimentation have been selected from results of previous soil testing. The K-value has been plotted both against the lime content and the clay content of the soil (part $< 16\ \mu$) and also the latter against each other. The choice is made in such a way that the scale of each factor is wide. Besides, occurring correlations between soil factors, such as those between K-value and clay content, are eliminated as much as possible.

Professor Bondorff has pointed out that the calibration of the method must be attained by establishing correlations between the soil tests and differences of yield. By means of statistical methods, the relation between the factor concerned and the reaction of the crop is examined. It is investigated whether other factors affect this relation in such a way that they must be taken into account for the calibration of the soil test. It is not essential whether this is done by means of graphical or mathematical methods.

It is obvious that the reactions of the yields are of considerable importance for the calibration of the soil test. We agree with Professor Bondorff that relative differences are more suitable than absolute ones, as experience has shown us. Our practice is to express the yield obtained without dressing in percentages of the yield which can be obtained on the same field under optimum conditions in regard to the factor examined. Then this relative yield, expressed in percentages of the maximum yield, is a measure for the availability of the nutrient in question. Increasing amounts of the fertiliser are therefore added, in order to determine the complete growth curve for this soil. A drawback of this method is, however, that the real maximum capacity of the soil cannot always be estimated in this way, as the effect of large additions of the fertiliser sometimes remains below this. This danger is especially real in dry years, on soils with high fixing power, and especially on grassland.

Another drawback already indicated by Professor Bondroff is that the determination of relatively small differences in yields makes high demands on the accuracy of the experiments. Secondary factors, such as lodging of cereals, may be very disturbing too.

Other properties of the crop which may be of importance for the appreciation of the availability of soil nutrients may therefore be of great use. The determination of the content of the nutrient concerned in the plant, especially of a rather young crop, of visual deficiency symptoms which can be expressed in an arbitrary scale, of 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. A great advantage of the use of these indications is that they very often show differences in cases of ample availability of the nutrient by which the yield is not affected. The consequence is that many more data are available to the statistical analysis. A disadvantage of the use of these properties of the crop is of course that a verification is necessary if the yields react principally in the same way and that the results must be interpreted in terms of yields.

When this method is applied, the use of field-trials becomes less necessary. During the war, field experimentation on a large scale was less possible. Then we took large numbers of soil samples and samples of the young crop of single small plots throughout the country. P and K contents of soils and crops were determined and related to each other. The method proved to be very successful, especially on grassland. The soil test for Mg has recently been evaluated by means of deficiency symptoms of cereals observed in farming practice which were expressed in an arbitrary scale.

The relation between the intensity of these deficiency symptoms (mottling) and the yield was known from former investigations. It was easy, therefore, to establish also the relation between the Mg content of the soil and the yield.

As soon as results, sufficiently in agreement with each other, are obtained in a few years' time, the mean result will allow for a decision on the value of the test. This is not sufficient, however, for an advisory basis. It is necessary to know the amounts of fertilisers to be given at different fertility levels. Still more important is the knowledge of the long-term effect of the different intensities of yearly application of fertilisers on the status of the soil and the production of crops. For the former, different amounts of fertilisers must be applied on the experimental fields, for the latter long-term experiments are required.

These long-term experiments provide also an idea of the need of the different crops and of the total rotation.

For practical reasons, it will be impossible to continue these investigations indefinitely. They are expensive and take much energy. Only the close collaboration between the Experiment Station and the Agricultural Advisory Service has made it possible to accomplish this work. Scientifically, the problem is not completely solved, however. Differences between the results of series of experiments made in different regions or years require a further explanation. In this connection we are now returning to the application of the pot experiment. This method is not useful for basing on it the advisory work on soil testing, but it may be of great help to determine whether differences found in the field are essential. If this will prove to be the case, more fundamental studies may be carried out as to the causes of the different behaviour.

The advisory schemes are planned in consultation with all specialists concerned. This has been especially the case with the schemes for grassland which take care of the special requirements of grassland. This scheme sets a standard. The local advisers are charged with the practical application of the plan, which, however, could be slightly changed, if desirable ; this method is the same as the one used in Denmark and described by Professor Bondorff.

The value of each method of soil testing depends to a considerable degree on the stability of the soil status concerned. Lime status and phosphate status are rather stable and will not change very quickly under normal agricultural conditions. The status of potash and of magnesium on the other hand is much more variable. Further, the applicability of the test will be more limited if also other soil factors must be taken into consideration for giving accurate advice. This is more unfavourable in the case of potash and magnesium than with lime and phosphate.

The figures which follow give some information about the results of our investigations and may elucidate the foregoing.

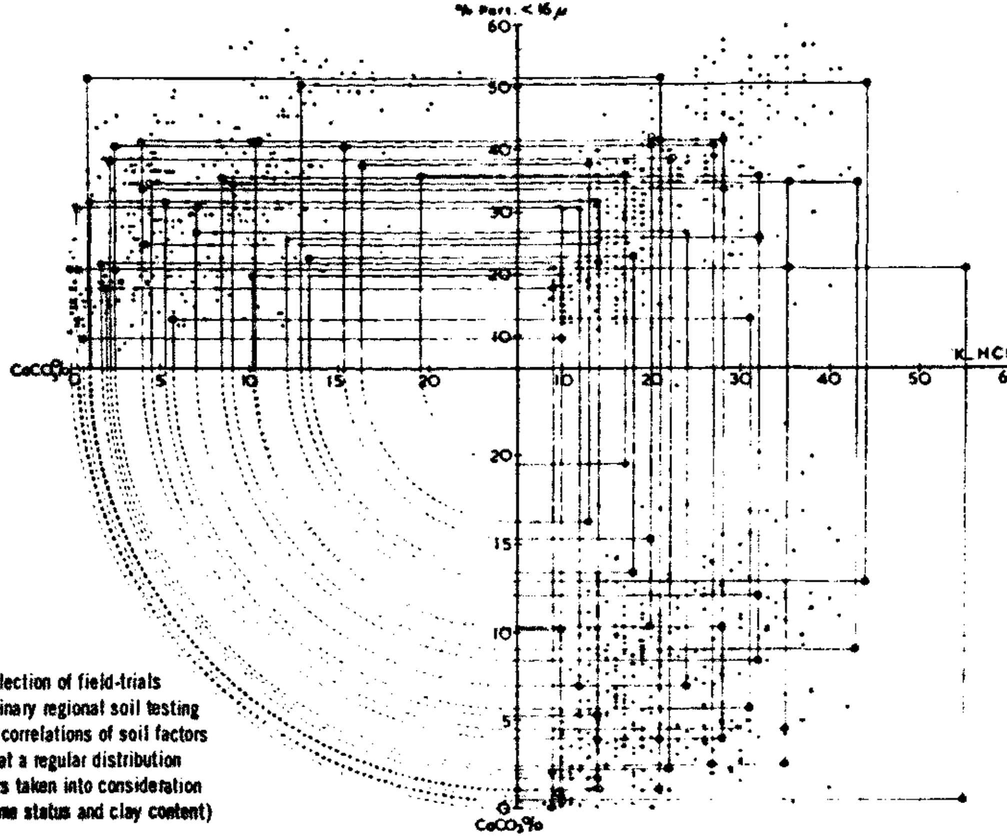

Fig. 1. Selection of field-trials after preliminary regional soil testing eliminating correlations of soil factors and aiming at a regular distribution of all factors taken into consideration (K-value, lime status and clay content)

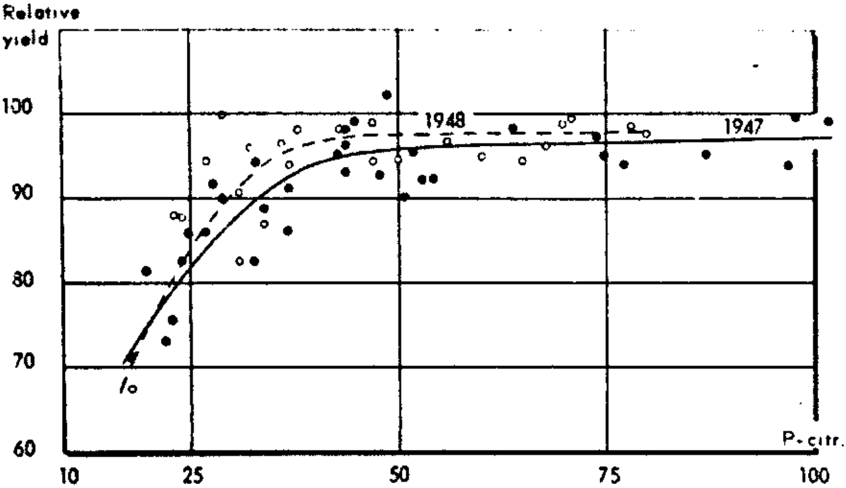

Fig. 2. Relation between P-citric acid number of grassland and relative yields (yields obtained without P in % of yield obtained on the same field with ample P) on marine clay soils in the northern and north-western parts of the Netherlands in 1947 and the western part in 1948. There is a very good agreement.

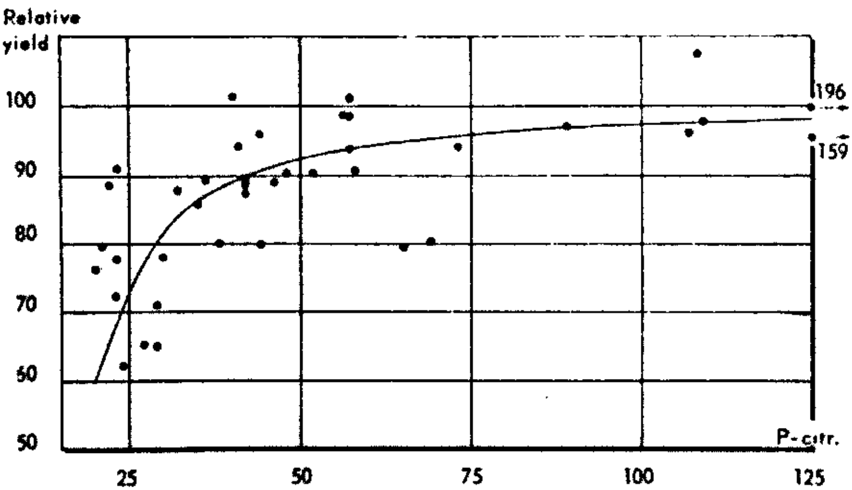

Fig. 3. Relation between P-citric acid number and relative yields on peaty soils. Rather bad correlation.

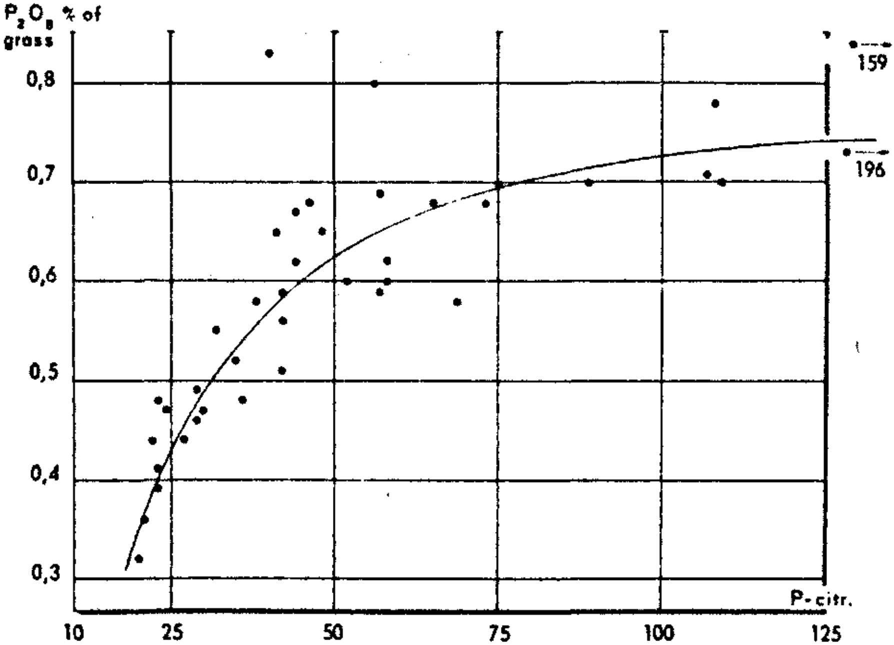

Fig. 4. Relation between P-citric acid number and P_2O_5-content of grass not dressed with phosphate (corrected to N% of grass = 1.8%), bearing on the same experiments as presented in figure 3. The correlation is much better.

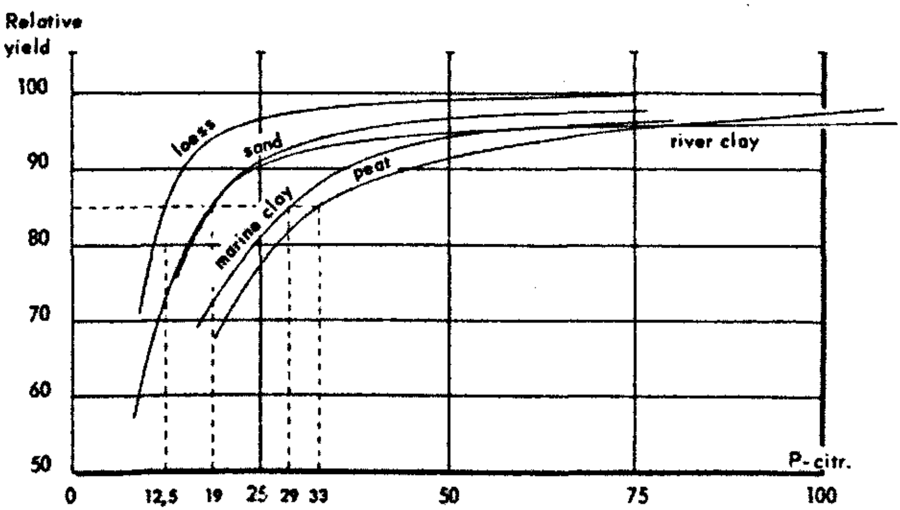

Fig. 5. Average relations between P-citric acid numbers and relative yields as found on marine (3 years) and fluviatile (1 year) clay soils, loess soils (2 years), peaty soils (2 years) and sandy soils (3 years). These averages provided the foundation for an advisory scheme.

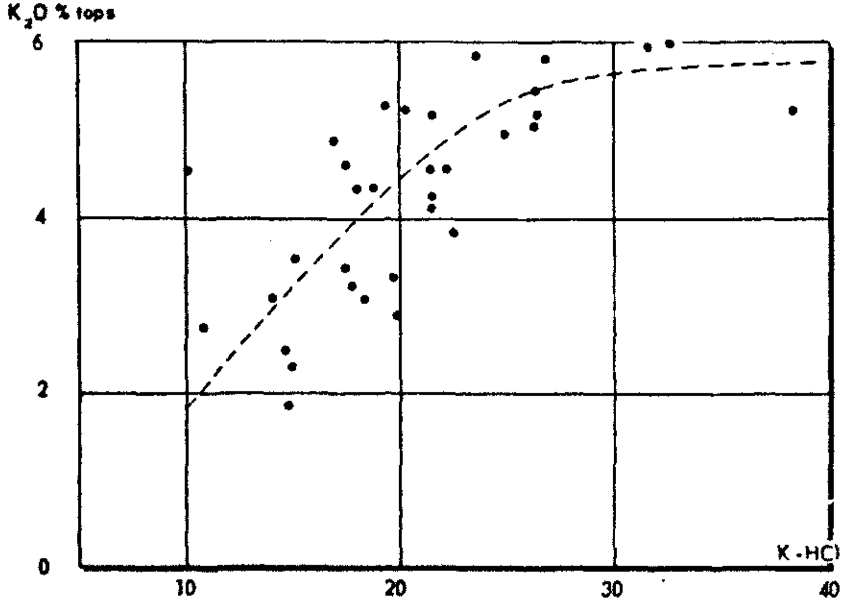

Fig. 6. Relation between exchangeable potash and the K_2O content of potato tops.
A. No corrections.

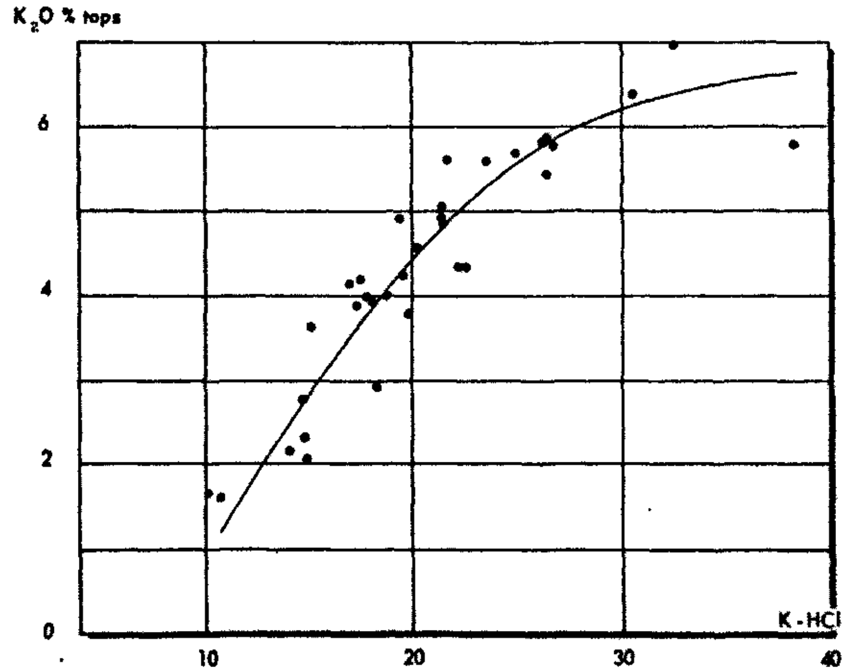

Fig. 6. Relation between exchangeable potash and the K_2O content of potato tops.
B. After elimination of the influences of lime status and clay content (showing high correlation).

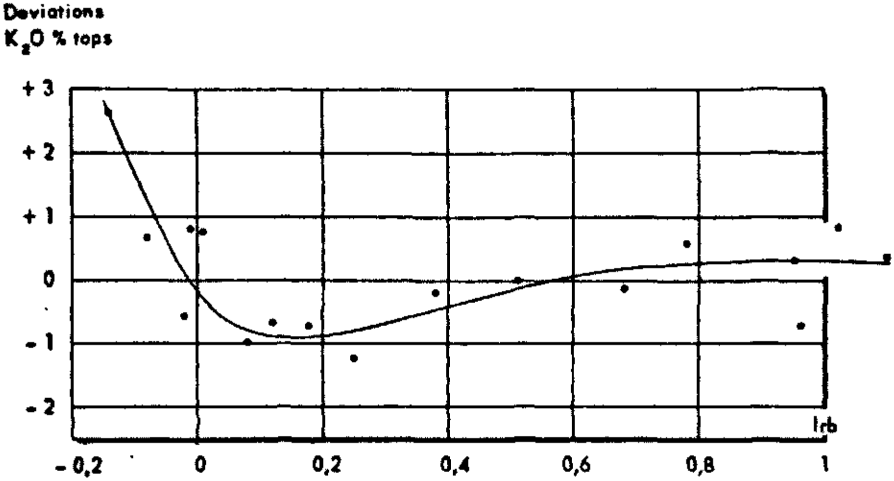

Fig. 7. Relation between lime status (lrb-value) and K_2O-content of potato tops (deviations from the mean content) after elimination of the influences of K-value and clay content (showing i.a. lime-K antagonism).

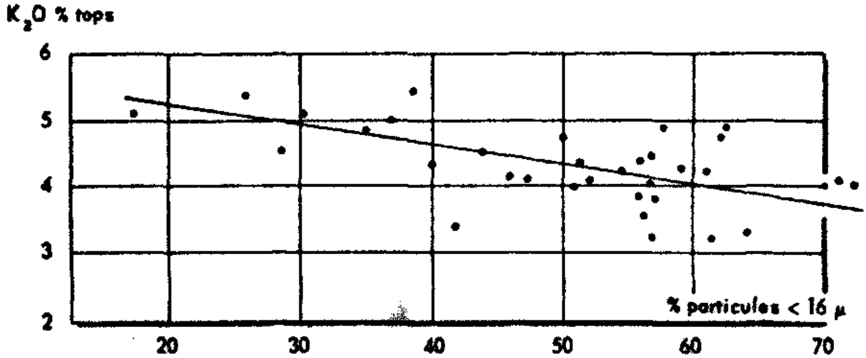

Fig. 8. Relation between clay content (particles < 16 μ) and K_2O-content of potato tops after elimination of the influence of K-value and lime status. Heavy soils need a higher K-value.

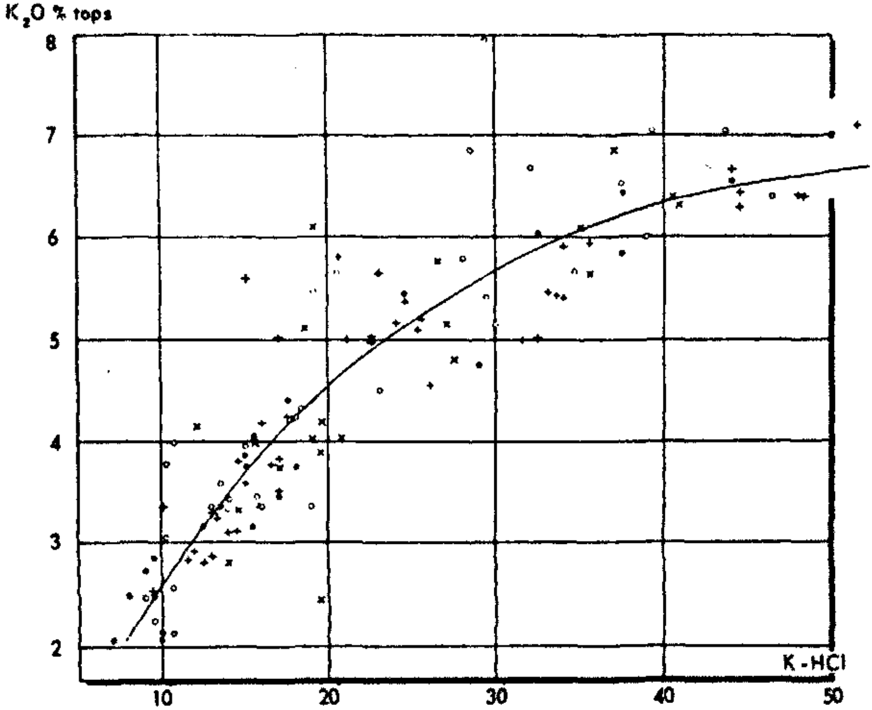

Fig. 9. Relation between exchangeable potash and K_2O-content of potato tops in a pot experiment with clay soils of different origin. No significant differences were noted though the field experiments had given no concordant results.

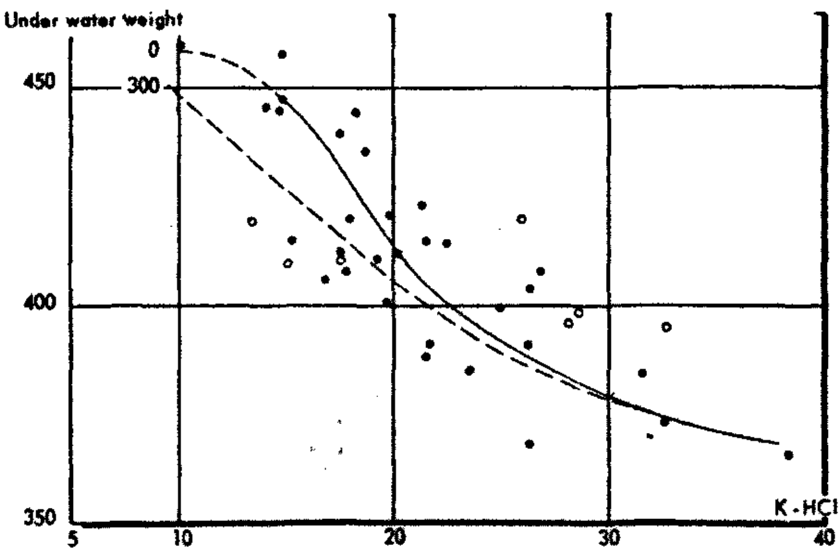

Fig. 10. Relation between K-value and "under water weight" of potatoes. The latter is used here with success as an index for the value of the soil test.

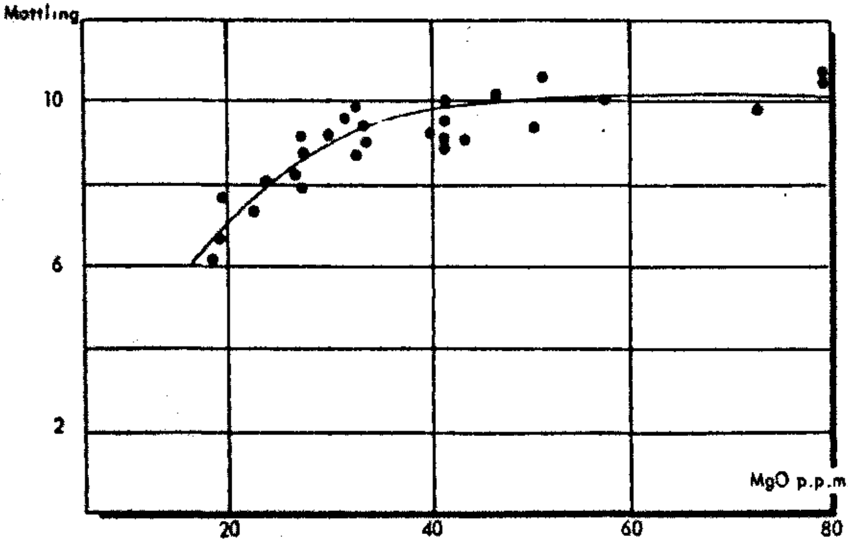

Fig. 11. Relation between Mg-value and mottling of cereals (after corrections). Visual deficiency symptoms may be of great use for the calibration of a soil test.

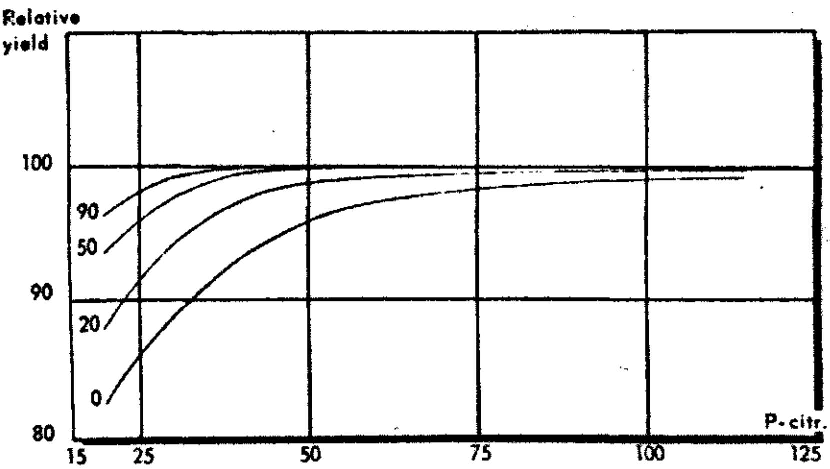

Fig. 12. Relation between P-citric acid number and relative yields of grass obtained with different P_2O_5 dressings. Experiments with increasing amounts of the fertiliser enable the determination of the quantity needed at different phosphate levels of the soils. Note that the effect of the fertiliser is much greater than the effect of soil phosphorus (cf. Bondorff).

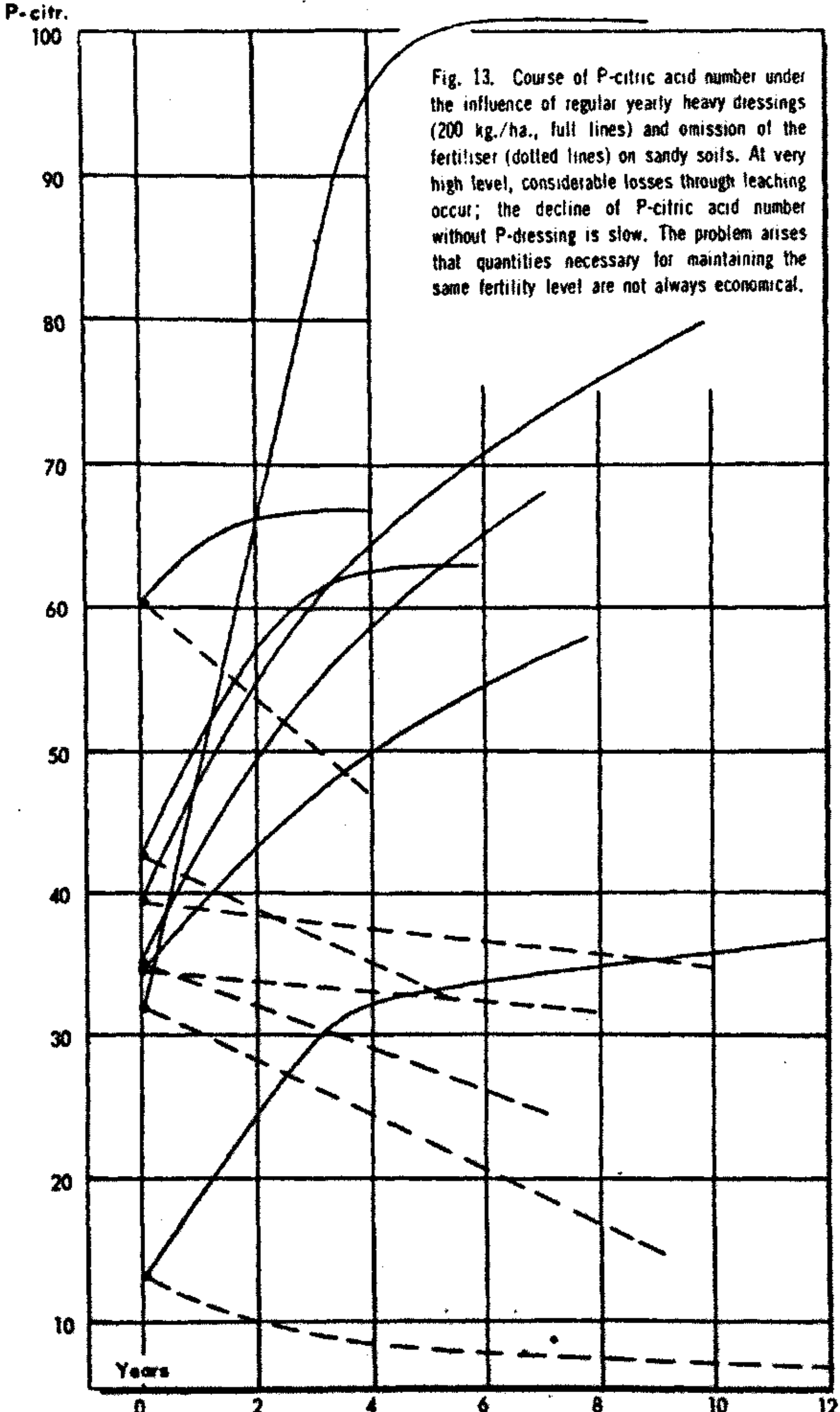

Fig. 13. Course of P-citric acid number under the influence of regular yearly heavy dressings (200 kg./ha., full lines) and omission of the fertiliser (dotted lines) on sandy soils. At very high level, considerable losses through leaching occur; the decline of P-citric acid number without P-dressing is slow. The problem arises that quantities necessary for maintaining the same fertility level are not always economical.