SESSION II

THE DEVELOPMENT OF SOIL FERTILITY RESEARCH IN THE NETHERLANDS

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1. *Introduction*

International congresses and committee meetings have had the inestimable value of establishing contacts between investigators from all countries and facilitating an efficient exchange of scientific data. Joint research has, however, so far been confined to methods of soil research with a bias towards laboratory work. This also applies to the joint labour of testing laboratory methods for the determination of the potash and phosphate needs of soils (Oxford 1935, Königsberg 1936 and Stockholm 1939). The present time with its many possibilities of communication and exchange of views may be ripe for all sorts of studies of a specialistic nature that are based on jointly organized field-trials. The advantage would be that in the co-operating countries interest would be focussed upon the problem of soil fertility and its importance for practical farming and the national economy.

With this object in view this paper on the development of soil fertility research in the Netherlands will especially refer to the close co-operation between field and laboratory experiments, which may be called a special characteristic of this development. This fact, we trust, may be a sufficient justification for choosing a subject which specifically deals with experience in our own country.

2. *General characteristics of the development*

The lectures delivered on "Soil Science and its application in the Netherlands" during the Fourth International Congress of Soil Science at Amsterdam, naturally touch various aspects of fertility research, although it was not emphasized as a central point of discussion.

Agricultural research in the Netherlands, which was not developed until the end of the 19th century, was with its small staff of scientific workers at the time confronted with so many problems of a diverse nature, that little attention could be devoted to soil scientific questions.

The characterization of the heavier soils was then based on the determination of weathering silicates, the mechanical composition, the humus and calcium carbonate contents and later also on the adsorption capacity and the mutual relation of the exchangeable cations. With the aid of these factors and a general knowledge of the profile and the agro-hydrological condition of the soil it was possible to draw a comparison between the different clay districts and to approach the value of new areas. The extent of this soil survey was comparatively small, however. Its character returns in later years in the chemical and physical soil descriptions in connection with hydrological problems (1).

The many lighter soils (especially the diluvial sandy soils) soon claimed the attention of agricultural research, because the cultivation of crops was threatened by deficiency diseases. First it was the "Veenkoloniale Haverziekte" (grey spot disease), occurring after overliming of these humic sandy soils, which could be remedied by applying sulphate of manganese. Later, frequent mention is made of three soil defects, i.e. "Veenkoloniale Haverziekte," "Hooghalense Ziekte" (low pH)[1] and "Ontginningsziekte" (reclamation disease)[2], and an attempt was made by regulating the lime status to create favourable growing conditions (2). The investigation of the lime status dominated soil fertility research for a good many years.

It is characteristic of the Netherlands that nearly half its agriculture is carried on on diluvial sandy soils that are poor in plant nutrients (content of particles $< 16\mu$ less than 10% and humus contents of 2 to 14%). It is, therefore, not surprising that farmers soon began to appreciate the possibilities offered by the developing fertilizer industry. Also older clay soils which had been under cultivation for several centuries and had been exposed to the leaching influence of a surplus of rainwater (26% drainage water of the average of 705 millimetres rainfall), showed a favourable reaction to fertilization. Moreover, the rapidly increasing population (at present 275 per square kilometre) necessitated an intensive use of the soil and stimulated the reclamation of heath and moorland.

The following table gives an idea of the increase in population and a rise in the use of fertilizers.

Year	*Population*	*Use of Fertilizers in Tons of 1,000 kgs*		
		N	P_2O_5	K_2O
1920	6,865,000	25,000	70,000	2,000
1930	7,936,000	60,000	100,000	90,000
1940	8,923,000	100,000	110,000	110,000
1950	10,200,000	164,000	121,000	150,000

The above quantities are applied to 2,400,000 hectares of land under cultivation (1,080,000 ha. arable and horticultural land and 1,320,000 ha. grassland), i.e. 73% of the total area. If at present the average dressing of grassland (predominantly permanent grassland) is assumed to be 60 kgs N, 40 kgs P_2O_5 and 30 kgs K_2O per ha., the average quantities for arable land are 80 kgs N, 65 kgs P_2O_5 and 100 kgs K_2O per ha.

From this it will be clear that soil fertility research early in the 20th century was first and foremost required to state where, in what quantities and in what form fertilizers should be applied. In those years the important point was to raise the yield per ha. as much as possible. In a country like the Netherlands it was (and is) almost impossible to leave land with a rather poor soil to occupy land in a more fertile region. By dint of hard work and intensive manuring reclaimed heath and moorland could be rendered productive. In fact, soil testing acquired increasing importance since about 1920 and re-

[1]Much later it was shown that magnesium deficiency played an important part in the development of this disease (3).

[2]A cure was effected by adding town refuse compost and sulphate of copper, respectively. MULDER proved the cause of this defect (4).

ceived a fresh stimulus by the foundation of the Soil Testing Laboratory. Investigations were not confined to soil research ; due attention was also paid to the usefulness of chemical crop research for the determination of the various aspects of soil fertility. The applicability of the various methods was subjected to a severe test. Not only the yield, but also the quality of the crops was taken as a measure of the soil fertility. In this connection also the relation between single soil values and the botanical composition of grassland may be referred to (5).

However, the system of single values, which was gradually developed, should not only be looked upon as a means of providing dressing advice for the benefit of farmers. It has, especially through the efforts of O. DE VRIES, expanded to a system of soil fertility analysis.

Besides easily variable factors related to the fertility status, factors that are difficult to vary and which are related to the more permanent characteristics of the soil, were incorporated as single values in this system. This led to regional investigations, the results of which could be compared.

The importance of soil survey and soil mapping has been emphasized especially since 1940 by the Agricultural University at Wageningen (6). The results of the work of the Soil Survey Institute were put forward in 1950 on the occasion of the Fourth International Congress of Soil Science in an English edition of a book by C. H. EDELMAN : "Soils of the Netherlands." Also, city and rural planning, a necessity because of the steady increase in population, availed itself of the results of soil research. As far as the problem of soil fertility is concerned, it frequently proves that so much independent significance, in a quantitative respect, should be attached to soil factors which can be distinguished in the units of the Soil Survey, that their combination into units leads to a too simple representation of the soil fertility. Of late years a close co-operation has developed between the work of the Soil Survey and the above-mentioned direction of the single values.

3. *From the determination of single values to a system of soil fertility analysis*

It requires considerable specialized study to recognize a factor of soil fertility and to express it in a figure. But it is equally important to test the single value thus obtained for its significance. In industrial language this may be called a semi-technical application of a method. The specialist investigator in this way acquires a larger sphere of work and may come to realize the limited significance of his creation.

In testing the single values, large-scale fertilizer experimental fields and other trial-fields have been employed. Soil fertility is determined by means of field-trials and laboratory research should rather be looked upon as a link between trial-field work and farming practice. The obtaining of data concerning soil fertility and the testing of single values have therefore gone hand in hand. The development of field experimentation is inconceivable without soil research and other laboratory work. However, in the following chapter it will be made clear that in connection with the numerous uncertainties and interactions many difficulties attach to the rendering of advice to individual farmers on a basis of single values.

Investigations have taught us that the single values in respect to their influence on the soil fertility, cannot be considered separately but have to be studied in their interactions. It is not only the interplay of fertilizing factors we are concerned with, but also the influence of more constant soil factors upon these (humus and clay contents, lime status, etc.). This interaction required the laying out of series of trial-fields and trial-spots, distributed all over the country, and the development of a field-trial technique. Thus the knowledge of soil fertility was enlarged to a high degree. It proved to be possible to make a thorough soil fertility analysis of an agricultural region and to use it in evaluating agricultural conditions of the whole region (7).

The relations obtained between the results of field and laboratory experiments call for an interpretation. Biological knowledge of the habits of the crops and physical, chemical and biological insight into the processes in the soil are indispensable. For example, the study of ion activities may contribute to a correct understanding of the types and the mutual level of the yield curves (8). It is remarkable to what extent in general more fundamental research can be directed and promoted by a systematic elaboration of these single-value tests. It has led us to the conviction that relations between single values can form an important contribution to physical-chemical soil research of a more fundamental character. It goes without saying that in this respect, too, allowance should be made for interactions.

The execution of the above-mentioned combination of field and laboratory research naturally requires a well-equipped mechanism for trial-field management and soil testing, which in its turn tends to stimulate the development of this system of investigation. The fact that the application of the results of soil testing is very closely connected with the results of field research is the cause that the latter exerts a preserving influence, and is sometimes inclined to be conservative. Conversely, soil testing with its direct interest in farming practice, aims at quick and cheap determinations, so that there is hardly any risk of rigidity in the determination system selected. It will be clear that a uniform system of soil testing which is carried out throughout the country, is a first requisite for the control of the soil fertility of the whole country.

The Advisory Service, which has greatly extended in the last few years, constitutes an indispensable support in developing the system of soil fertility research and promotes its efficiency to a high degree. Finally it is worth noting that agricultural colleges and schools are of inestimable importance, because education and agricultural training impart confidence in scientific methods.

4. *Scientific development of soil fertility research on a basis of single values*

Working with single values in field-trials leads to a preference for many experimental treatments in series with a small number of, or even no, parallel plots to a smaller number of experimental treatments with many parallel plots (9).

The reason is that a single value represents a soil status which is subject to variations from spot to spot and also shows differences between parallel plots of one treatment. This is an inducement to plot data of crops (contents, yields, qualities, etc.) against the single values of all the trial-plots and also to represent the results graphically. This procedure was even encouraged because of the aim to obtain optimum yields by means of fertilizers. The realization of complete yield curves was thus attempted. Working with parallels is especially practised when it is not possible, or not immediately possible, to express quantities of fertilizers applied in a change of soil factor. Lime experiments and nitrogen trial-fields may be regarded as extremes in this respect. In fact, the addition of lime soon brings about a change of the lime status, whereas as yet there is no question of an exact measure for the "nitrogen status" of the soil. Fertilizer trial-fields with phosphate and potash are in an intermediate position in this respect. In a series of fertilizer trial-fields with phosphate or potash, respectively, we are concerned with both "status" and "quantity." In this way it is possible to express yields with a different "status" as percentages of the optimum yields and to plot the relative figures thus obtained against the single values of the untreated plots. In the further development of our research it appeared that this procedure may include a restriction, i.e. a relative yield may be high because the optimum yield remains low through some limiting influence. The latter is often evident in fixation phenomena. It should, therefore, never be omitted to plot the absolute yields of the plots treated in the same way from all the experimental fields of one series (first the untreated plots) against the single values. This development led to the replacement of series of simple fertilizer quantity fields, laid out in an agricultural region, by experimental spots distributed over this region and possibly receiving diverse treatments. Their results may be treated by a graphic method of statistical analysis—the so-called polyfactor analysis (10).

The yield curves obtained by the graphic method are always drawn by hand through the dot diagrams. An attempt is always made to reduce the deviation of dots by eliminating the influence of other single values, after which a correction of the curves can be introduced. We are here concerned with problems of curvilinear adjustment. Investigators of different training and working in different spheres of activity have employed this working method, which no doubt brings out the perspectives of their investigation more clearly than would otherwise have been possible (11). In general, little consideration has been given to the mathematical basis of the method. The criticism that the reliability of the results obtained may possibly have been sacrificed to the clearness is justified. The problem is now being thoroughly studied by mathematicians.

In former years observations were given on standard deviations of various aspects of trial-field work and on analysis methodology. First this work dealt with questions like the most desirable size of the experimental plots, standard deviation of the yield determination and of the analysis of the soil (12) and later it was continued by evaluating usefulness of various methods of soil research. The latter problem was accurately studied and the standard deviations of soil sampling, of analysis and of yield determination, together with methodical error and the efficiency, were distinguished (13).

The methodical error in a restricted sense is caused by the insufficient agreement between the ways in which the various methods give a measure for the characteristic of the soil to be determined. The efficiency refers to the extent to which a method can express the reaction of the crops. Several methods of determining phosphate and potash were compared and studied in relation to the crop yields; for phosphate :- P-citric acid, P-number (soluble in water at 50°C,) P-HCl, P-DIRKS-SCHEFFER, P-content (of the crop in an early growing stage), P-NEUBAUER, P-Aspergillus; and for potash :- K_2O-1N HCl, K-5% HCl, K-Asp., K-Neub. and K-content of the crop. Also several methods of determining the pH or the lime status of the soil were subjected to a critical examination, i.e. pH-H_2O and pH KCl (without drying the samples and after drying, respectively) and the V-number (degree of saturation). In this way valuable data were obtained.

5. *Soil fertility in the Netherlands and its control*

It is possible through co-operation between field and soil research to make an estimate of the possibilities of improving the fertility of the soil by manuring and soil improvement. This was done after the Second World War with respect to various factors (14). For example, the yield of arable land could be increased by 15-20% on an average in case of a more rational application of fertilizers, i.e. by 10% in case of a more efficient addition of nitrogen, by 1-2% with phosphate, 2-3% with potash and 3% with lime. Also with magnesium and trace elements improvements could be made. For permanent grassland this percentage was estimated at 20% through improving the phosphate status and potash status of the soil, provided at the same time other improvements were effected, e.g. in drainage conditions. The possibilities with nitrogen on grassland are naturally great; the yield could definitely be increased by 40% on condition that changes are also introduced in the management of the farm.

More intensive applications of organic manure on arable land, together with improvement of the soil structure, would bring about considerable improvements in many agricultural districts. But as yet it is impossible to give an average percentage. The methods to describe the nitrogen condition of the soil and the soil structure, which are needed to form a link between the results of the field-trials and the farming practice, are still in process of experimentation at the laboratory and are tested on the trial-fields. The possibilities of improvement of permanent grassland through a more intensive use of organic manure are, on the strength of statistical investigations, estimated at 5%.

These estimates tend to focus our attention on factors which are too much neglected. Thus it proves that losses of lime and magnesia are still insufficiently supplied, so that deficiencies in these respects are increasing.

In the Netherlands, effecting improvements is left to the initiative of the farmers, who are assisted and instructed by the Advisory Service. It is our opinion that regional investigations and conjointly organized improvements may, with Government support if necessary, ultimately lead to the desired end. In a few cases this is put into practice. In this connection consideration is given to the possibility of effecting improvements in the fertility status during re-allotment and reclamation operations. Co-operation between soil survey and fertility analysis will doubtless have a beneficial effect on regional development.

Two other investigations of considerable extent may be worth mentioning: production level research and the investigation of the agro-hydrological condition of soils under cultivation. The former research, conducted by the Central Institute for Agricultural Research, deals with the determination of the yield in 3,400 places (1 : 600-700 ha.) over a few years, at the same time taking account of many details about farm management, crop cultivation and soil fertility. The results are statistically represented and treated in various directions. The investigation of the agro-hydrological status of the soils, which is financed from the M.S.A. funds, aims at procuring rational methods to control the water condition and to acquire an efficient distribution of the available amount of water. In both these investigations measuring and weighing will, in many cases, be replaced by estimations and advantage will be taken of the estimation technique which has been developed in the last few years (15).

6. *Final remark in connection with the task of the Commission for Soil Fertility and Plant Nutrition of the International Society of Soil Science*

In the foregoing chapters we have not confined ourselves to a survey of soil fertility research but have also pointed out the importance of putting its results to practical effect. It seems to us that this close contact between field and laboratory research, which is the best stimulus in this direction, should be the basis for an international exchange of information. Our International Society can do much along these lines, the more so as its scope of activities is getting more and more extensive. Commission IV will, by means of results of fertility investigations in the countries and regions concerned, be in a position to indicate the lines on which the international co-operation of the commissions for Soil Physics, Soil Chemistry and Soil Biology should be conducted and to acquaint many soil scientists of characteristic differences in soil fertility and production level between countries in the same climatic zone.

It will not be difficult to find subjects which lend themselves to international experimentation and discussion. We would suggest, for example, the relation between organic fertilizers, structure and nitrogen condition of the soil or the exchange between lime and potash status or the various aspects of the phosphate problem.

It is our intention to illustrate these subjects by examples at the meeting.

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