ROTHAMSTED RESEARCH

Report for 1935

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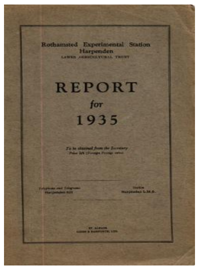

Soils

Rothamsted Research

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could be eliminated. This purpose was accomplished, and designs such as randomised blocks and the Latin square are now superseding the older types of lay-out in almost all classes of agricultural experiment, both in this country and overseas.

During the last few years attention has been devoted to methods of increasing the efficiency attainable by simple randomised blocks and Latin squares, and to methods of widening the scope of a single experiment so that several problems can be investigated concurrently. *Factorial designs* have been developed, in which all combinations of different levels of several treatments (or factors) are included. A simple and very effective example of this type of design is the 27 plot experiments of the factory sugar beet series. In these experiments all 27 combinations of double, single and no dressings of each of the three standard fertiliser components, nitrogen, phosphate and potash are represented, only one plot being devoted to each treatment combination. Each plot is in effect used three times over, once to assess the value of nitrogen, once for phosphate and once for potash. In addition, information, which would be wholly lacking if three separate experiments, each confined to one of the three fertilisers, were used, is obtained on possible variations in response to one fertiliser at different levels of the other two. Such factorial designs, therefore, represent a great advance in experimental technique, and they will probably supplant the simpler methods in the same way as randomised blocks and Latin squares have supplanted the older systematic arrangements.

The attention of the department has also been directed to problems of sampling, which are of immense importance in agricultural experiments. The most efficient technique in any given instance can be determined only by statistical methods ; indeed if statistical principles are not borne in mind sampling may be almost unbelievably inefficient. An example of the rapid advances in knowledge that can be obtained by the discriminating use of a good sampling technique, applied co-operatively by workers at several centres, is provided by the sampling observations of the growth of the wheat crop, which are described in a later section.

SOILS

The chemical and physical work consists in attempts to discover the composition and constitution of the soil, and to follow the changes taking place therein.

The clay is recognised as one of the most important components and much work is being done on it in the Chemical Department. Dr. Nagelschmidt has found by X-ray analyses that its commonest constituent differs from all known minerals, but is apparently related to halloysite : he is also studying the swelling of the montmorillonite lattice in presence of water. This investigation requires continuous access to very costly physical apparatus and we are greatly indebted to Sir William Bragg for allowing all that side of the work to be done in the Davy Faraday laboratory of the Royal Institution.

Soil Analysis. Considerable attention has been given to the old problem of finding some chemical means of forecasting the probable effects of fertilisers. For soils suffering from some serious

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deficiency this is relatively easy, but for soils that have been reasonably well farmed and manured none of the present methods is adequate. An examination of some 15 different methods was recently made by members of the International Society of Soil Science, but none of them proved entirely satisfactory. The rapid methods put forward from time to time are liable to give misleading results. Dr. Crowther, in conjunction with Mr. Warren, Dr. Richardson, Miss Heintze, Dr. Nagelschmidt and other members of his staff is examining the soils of the various plots on which sugar beet and potatoes are grown, to discover how far the results of the field experiments accord with the expectations based on various methods of chemical analysis.

Soil Moisture. In the Physics Department, a notable achievement has been the straightening out of the difficult problems associated with the moisture relationships of the soil. For many years these have caused considerable difficulty: a scale has now been devised which introduces the same kind of order and simplification as the *p*H scale has done for soil acidity. This work is so important to soil workers that a summary of it is given here though the description is necessarily very technical.

When wet soil is placed in an atmosphere of fixed relative humidity (*h* per cent.), evaporation continues until the moisture content has been reduced to a value which depends on the nature and previous moisture history of the soil sample and on *h*. When evaporation ceases, the free energy of the water remaining in the soil is less than that of pure water in bulk by $\frac{RT}{18} \log \left(\frac{100}{p}\right)$ ergs per gram. Dividing by the gravitational acceleration *g*, this free energy difference is given by the height in centimetres of a column of water that expresses, in effect, the " suction " with which the remaining water is retained; or, looked at another way, the effective height above a free water-table. Evaporation into a 50 per cent. relative humidity atmosphere develops a suction in the remaining water equivalent to 1,000,000 cm. of water, a column higher than Mount Everest. The difficulty of comparing such suctions with those developed as the result of drainage to a water table, which are of the order of 1,000 cm. and less, has been met by using the logarithms of these figures. By analogy with Sørensen's logarithmic acidity scale the symbol *p*F has been used (F being the recognised symbol for free energy).

The suction force exerted by the roots of plants which have just reached the " permanently wilted " condition is usually between 10,000 cm. and 20,000 cm., or between *p*F 4.0 and *p*F 4.3. There are great experimental difficulties in the way of measuring evaporation into atmospheres more humid than about 95 per cent. saturation Hence 60,000 cm., or *p*F 4.78, the suction developed by evaporation into an atmosphere over 10 per cent. sulphuric acid (95.6 per cent. relative humidity) is about the lowest value obtainable in this way. On the other hand, the highest value obtainable by vacuum suction through a filter is 1,000 cm., or *p*F 3. Fortunately, freezing point determinations enable this gap to be bridged. One degree centigrade freezing point depression corresponds to a suction of 12,700 cm. or *p*F 4.1.

Mr. Botelho da Costa, under the direction of Dr. Schofield, has used the improved freezing point technique mentioned in the last report to measure the *p*F of the water that remained in seven soils, of widely different character, when beans growing in them became "permanently wilted." The values so determined fell between *p*F 4.0 and *p*F 4.4, although the corresponding moisture contents ranged from 2.9 to 21.6 per cent. of dry soil. Taking the mean value of *p*F 4.2 and reading the corresponding moisture content from the curves plotted from the freezing point measurements, the values obtained differ on an average by only 0.7 per cent. from the moisture contents found in the wilting experiments. The greatest difference was only 1.2 per cent., which would be of small consequence in field measurements.

The moisture content of a soil at permanent wilting does not bear a constant ratio to the "moisture equivalent" determined in the Brigg-McLean centrifuge as these authors claimed. The freezing point determinations show why this is so. For a medium textured soil the "moisture equivalent" corresponds to about *p*F 2.9. This was confirmed by the freezing point measurements which showed that the curves connecting *p*F and moisture content differ in *shape* from soil to soil, and for the seven soils examined the ratio of the moisture content at *p*F 2.9 to that at *p*F 4.2, instead of being constant at 1.84, varied from 1.5 to 5.3.

By using the *p*F scale the results of measurements by direct suction, centrifuge, freezing point and evaporation into atmospheres of controlled humidity can be plotted on the same graph and curves connecting *p*F and moisture content can be traced from saturation (*p*F 0=1 centimetre suction) to oven dry (approximately *p*F 7). This work has brought into prominence the great importance of distinguishing between wetting and drying conditions. The suction needed to withdraw water from a moist soil is, in general, greater than that against which water will enter the soil at the same moisture contents. This fact, coupled with the slowness of wetting of clay by water at *p*F 3 or above, has been shown to account in a general way for the characteristic moisture distributions met with in the field.

SOIL MICRO-ORGANISMS

The growth of the plant, in nature is determined not only by chemical and physical soil factors but also by the soil micro-organisms, which are studied in the Micro-biological, Bacteriological and Fermentation Departments. The more these organisms are investigated, the more numerous they appear. Twenty-five years ago, the bacterial population in one gram of soil (about a salt-spoonful) would have been assessed at about 5 to 10 millions. It is now known that the figures are very much higher. A gram of field soil may contain several thousand million bacteria, many thousands of protozoa, millions of actinomycetes and fungi, in addition to an unknown number of eel-worms, besides other organisms not invariably found, either because they are not always present or because the technique is defective. The greater accuracy of modern bacterial counts is due to the method of counting bacterial cells in soil under

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