ROTHAMSTED RESEARCH

Report for 1933

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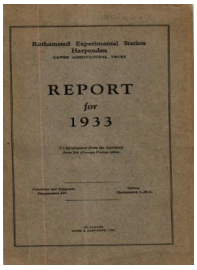

Physical and Chemical Properties of Soil

Rothamsted Research

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especially the transition from the early stage in the life of grass and cereals when the plant is rich in protein and in minerals, to the later stage when it contains much cellulose. This completely alters its feeding value and much affects the return a farmer obtains from his fertilisers.

These studies of cellulose will be greatly facilitated by the collaboration of the Textile Physics Department of the Leeds University, Mr. Astbury having kindly undertaken the X-ray photography of the various samples whereby their intimate structure is revealed.

THE NATURE OF THE SOIL

Field experiments necessarily remain purely empirical and limited in value until sufficient is known about the soil to show how far the results obtained on one field are likely to be obtained on another. Laboratory investigations of the soil are therefore made on the physical, chemical and microbiological sides.

PHYSICAL PROPERTIES OF THE SOIL

These are studied in the Physics Department. B. A. Keen's well-known investigations of the soil moisture relationships have formed the basis of much subsequent work, including that of W. B. Haines, which showed that the old " equilibrium values " of soil moisture content had no actual existence although certain characteristic moisture contents could be recognised. Some of these are now being studied by G. H. Cashen using sensitive electrical methods ; they correspond to some kind of combination with successive but uniform increments of moisture. The well-known " sticky point " appears to be the seventh of these stages.

Kaolin appears to behave like clay, and as its chemical and physical composition are better known than those of clay, it has proved useful in the interpretation of the clay phenomena.

Water, however, is not the only liquid with which the clay enters into some sort of combination. E. W. Russell has studied the behaviour of clay and various organic liquids, using the change in specific volume of the clay when immersed in them as a measure of the degree of the combination taking place. So far as can be ascertained, only polar liquids interact with clay, and the extent of the interaction (i.e. the reduction in specific volume) is approximately proportional to :

(1) The number of exchangeable ions the clay can hold in equilibrium with a buffer of pH7 ;

(2) The mean charge density on the surface of the ions ;

(3) Some property of the clay expressed by the shape of the clay titration curve.

When the liquids evaporate from the wet paste the clay particles tend to cohere, forming aggregates or crumbs. This occurs, however, only in polar liquids, and it is marked only when the clay has an appreciable base exchange capacity, when its particles are small, and the exchangeable cations and polar groups of the liquids are also small.

All these phenomena can be explained on the hypothesis that the exchangeable ions of the clay particles interact with the molecules

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of the liquid if these are polar, the interaction being the simple orientation of the dipoles by the electric charges on the ions and the clay. This hypothesis promises to be useful in furthering our knowledge of clay and of crumb formation in soil. E. W. Russell having been awarded a Rockefeller Fellowship, has proceeded to Professor Patrick's laboratory at the Johns Hopkins University, Baltimore, to continue the investigation, using the special high vacuum technique which has been developed there.

A new line of investigation, the interpretation of which is not yet in sight, has been opened up by R. K. Schofield. The curves expressing the relation between calcium uptake by different clays from calcium salt solutions of different pH values vary according to the clay, but the variation occurs only at pH values below about 9.8 ; above this the curves are all similar. Whether this is a specific property of the calcium ion, or whether other ions behave similarly, is not yet known. The results are, however, curious and almost certainly conceal some property of considerable importance.

The clay investigations are already throwing light on other problems besides those relating to the soil. G. W. Scott Blair is making with dough a series of experiments parallel to those already made with clay, dealing especially with viscosity. He and R. K. Schofield first cleared up a difficulty on the theoretical side by showing how to modify the ordinary Maxwell equation expressing the relation between rate of change of strain to rate of change of stress so as to make it fit the facts in regard to clay and similar substances. The new results are now being used to study the stickiness of dough in association with the Research Institute of the Flour Millers' Association. This particular property is much used by the baker in assessing the value of the dough ; it is being estimated by means of a Kachinsky balance. The rheogram measurements already described have been extended and for the first time the important elastic and plastic properties of dough have been expressed in absolute (c.g.s.) units, while standardised methods have been set up for preparing reproducible doughs from flour samples.

The effect of yeast on these various properties has been studied in conjunction with L. W. Samuel.

The important technical applications of these various results are worked out at the Flour Millers' Association Laboratory. The work affords an excellent example of the way in which a scientific investigation *properly done* may widen out wholly unexpectedly and throw light on problems far removed from those originally in mind.

CHEMICAL PROPERTIES OF THE SOIL

The work during the past year has been concerned chiefly with the plant nutrients in the soil. The fertiliser experiments at Rothamsted, Woburn and the outside centres are all organised from the Chemical Department, and a considerable part of the time of the staff is taken up with the chemical work associated therewith.

Side by side with the field experiments on organic manures, E. M. Crowther and his staff have since 1927 been studying their decomposition and that of crop residues in the soil, to find the relation between the production of " available nitrogen " and the nature of the organic material and the general soil conditions, including the time

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interval between addition of the material to the soil and utilisation of the nitrogen compound by the plant. The starting point was the remarkable fact that green manures, especially tares, do not keep up the productiveness of the light soil at Woburn for wheat. The conditions in the field favour rapid decomposition of the crop residues and loss of nitrate by leaching, but this is not the whole explanation. E. M. Crowther and H. H. Mann show that in pot experiments barley benefits from the nitrogen of the tares so long as it is sown immediately after the burying of the green crop, but it does not benefit from the nitrogen contained in the mustard. The effectiveness of the nitrogen speedily decays, however, and if the sowing is too long delayed, the cereal gains but little from the tares. This is not entirely a drainage effect, for it happens whether the soils have been leached or not. At Rothamsted the nitrate stored up during a summer or autumn fallow suffered a similar " decay " : it fell to a low level during winter. Yet the wheat crops that followed did not suffer in the same way : the yields corresponded more closely with the levels of nitrate present in autumn, and varying with the treatment, than to the uniformly low levels of the early spring. E. M. Crowther suggests two possibilities, both of which are being further studied : the nitrate may be converted by micro-organisms into an insoluble form which is later broken down and becomes available to the crop ; or it may be washed into the subsoil and held there till it is taken up by the crop. Usually the plant nutrients are supposed to be specially associated with the surface soil, and the subsoil is often neglected by chemists. The above results suggest that the production and utilisation of plant nutrients is related to the structural and textural characters of the whole of the soil profile.

In acid soils and on grass land, nitrate formation does not proceed far, and considerably more ammonia accumulates. Evidence is adduced that grass frequently or even normally obtains its nitrogen not from nitrate, but from ammonia.

Soil analysis. Now that so many field experiments are being made at outside centres by the Rothamsted staff or in association with them, it has become possible to take up once more the important question of soil analysis. Nothing in agricultural science has had a more chequered career. Hailed at the outset as a great scientific triumph, it had to be abandoned because its results were so often useless to the farmer. It is now recognised that two distinct problems are involved : soil analysis for advice in regard to manuring, and soil analysis for the characterisation of soils for purposes of soil surveys. Two groups of methods are therefore needed, and these are being worked out in the Chemical and Physical Departments.

For purposes of advice on manuring it is usual to adopt some " availability " method. A number of these have been devised and some are fairly well received on the Continent. They and others are being tested in the Chemical Department on the wide range of soils obtained from the replicated plots at our outside centres where, therefore, the actual manurial response is known.

For soil survey purposes, new methods of characterising soils are being studied both in the Chemical and Physical Departments, and then tested on groups of soils known to differ in properties. An important survey of the soils of a large rubber estate in Malaya is now

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being made, one of our former workers being out there for the purpose ; based on this survey is an extensive series of manurial trials. A comparison is being made of certain tropical and sub-tropical soils by some of these new methods to see how far the relations already found are likely to hold true generally.

This work will be facilitated by the investigations on the inorganic soil colloids now proceeding under E. M. Crowther. A new method has been worked out for the direct determination of aluminium in soil clays, and Sir William Bragg has kindly given facilities for using X-ray methods in the investigation of the clay structure.

Rare elements in plant nutrition. As for human beings and animals, so for plants, there are certain food substances which must be supplied, or normal growth does not take place. In one of the first investigations made by Miss Brenchley, at Rothamsted, small quantities of manganese were shown to be advantageous to cereals ; later work by Samuel and Piper at the Waite Institute, Adelaide, showed that in its absence the oat plant is specially liable to " grey speck " disease. The Chemical Department is now engaged in a study of availability of manganese in deficient soils liable to this disease.

Miss Warington showed that small quantities of boron are needed, and from various parts of the world there have since come accounts of plant diseases associated with boron deficiency. The appearance of this deficiency is less rapid in spring and autumn than in summer, but plants require boron whatever the season. Some of the effects of reduced hours of daylight superficially resemble those of boron deficiency, e.g. both may prevent flowering, but the characteristic effects are entirely distinct. One result of lack of boron is to reduce the uptake of nutrients, calcium being more affected than either nitrogen or potash.

Fertiliser from waste coal. In recent years various humic substances have been prepared from waste coal for which fertiliser value might reasonably be expected. Careful tests of materials supplied by well-known experts in coal chemistry have, however, failed to reveal anything of value to the farmer. Claims of better success have been put forward in Germany, but so far we have no evidence that these are justified.

LUCERNE AND THE NODULE ORGANISMS

The demand for cultures of the nodule organism still continues satisfactorily, and we are informed by Messrs. Allen and Hanbury that enough were sold last year to treat seed for 4,200 acres.

Meantime, H. G. Thornton is continuing the study of the relations between the nodule bacteria and the plant. He finds that the infection of the host legume increases very greatly at the time when the true leaves open. At that stage the root hairs exude something which apparently causes the nodule bacteria in the soil to multiply ; and, in turn, to produce something which causes the root hairs to curl ; and at the bend thus made they enter. H. G. Thornton has now isolated from the bacterial products a gum which causes the root hairs to curl and also to grow, so that it is either itself a growth stimulating substance or it is associated with one. Its action, however, is neutralised by a small quantity of nitrate in the presence

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