ROTHAMSTED RESEARCH

Report for 1953

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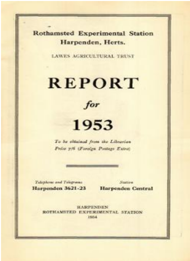
Rothamsted Experimental Station
Harpenden, Herts.

REPORT
for
1953

Physics Department

R. K. Schofield

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PHYSICS DEPARTMENT

R. K. Schofield

Thanks to financial support from the Research Council of Ontario, H. L. Penman was able to attend a meteorological conference in Toronto, to meet and visit Canadian workers in agricultural meteorology, and to visit four American centres of research in agronomy, hydrology and agricultural meteorology. At the request of the Research Council he prepared a report making recommendations for future research activity in agricultural meteorology in Ontario. He wishes to record his sincere thanks to the Council for their great generosity in sponsoring the visit, and to all in Canada and the U.S.A. who made a crowded trip so happy and rewarding.

H. R. Samson received the Ph.D. degree of London University, and returned to resume his duties with the Ceramics Section of the Australian Commonwealth Scientific and Industrial Research Organization. I. R. Cowan has transferred to the Sugar Research Department, Mandeville, Jamaica, where he will work under Mr. R. F. Innes with general guidance from Rothamsted. J. M. Bastos de Macedo, of the Instituto Superior de Agronomia, Lisbon, worked for seven months on the sorption of phosphoric acid by the different crystalline forms of ferric oxide which occur in tropical soils, and he will continue this work in Lisbon. F. Silva, of Medellin University, Colombia, has joined the department for ten months, having won a British Council Studentship.

J. L. Monteith joined the staff, but continued for a few months his work under Professor P. A. Sheppard at the Imperial College of Science. J. S. G. McCulloch visited agricultural meteorological stations in Germany with the assistance of a travel grant from the Agricultural Research Council.

Agricultural Meteorology

(H. L. Penman)

Irrigation

The summer rain in 1953 was sufficiently plentiful to reduce the irrigation requirement to very low values. Indeed, by ordinary

Woburn Irrigation 1953

Crop	Period	Rain, inches	Irrigation, inches	Plot	Yield	
Grass . .	27 Apr.–28 Sept.	12·1	—	ON_1	82·2	Dry matter (7 cuts), cwt./acre
				ON_2	95·0	
		12·1	5·6	CN_1	91·7	
				CN_2	108·4	
Sugar beet	27 Apr.–28 Sept.	12·1	—	ON_1	81·0	Sugar, cwt./acre
				ON_2	87·3	
		12·1	3·6	CN_1	80·1	
				CN_2	83·2	
Barley .	27 Apr.–10 Aug.	7·4	—	ON_1	23·7	Grain, cwt./acre
				ON_2	30·0	
		7·4	0·8	CN_1	23·8	
				CN_2	29·0	
Potatoes .	27 Apr.–6 July	4·5	—	ON_1	10·1	tons/acre
				ON_2	12·0	
		4·5	2·0	CN_1	12·0	
				CN_2	14·7	

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farming standards it was a summer in which irrigation would be dismissed as unnecessary. The table on p. 35 shows the yields for the watering extremes at two levels of nitrogen dressing.

Notes on weather and crops :

Weather. Rainfall was not much above average at any time, but evaporation conditions were poor, so that soil moisture deficits never became very big.

Grass. The seventh cut was late in October. The maximum irrigation was deliberately overdone, and lower rates were almost as effective : e.g., for 2·6 inches of irrigation the yields were : AN_1, 91·3 ; AN_2, 101·9 cwt. dry matter per acre. During the summer H. H. Mann has continued to keep his records of the content of grass, clover and weeds in the herbage.

Sugar beet. Irrigation was unnecessary.

Barley. The irrigation schedule had to be abandoned in June because of lodging on all the plots, but which was most severe on the high nitrogen halves.

Potatoes. A very good yield without irrigation was made even better by keeping the soil close to field capacity throughout the growing season.

With a new rotation starting in 1954 some changes are being made. The grass plots will be ploughed up and re-seeded with a pure grass strain ; main crop potatoes will replace earlies ; and a winter cereal will replace barley.

Micro-meteorology

I. F. Long has maintained the continuous recording of dry and wet bulb temperatures within and above the potato crop used for blight studies. To this equipment he has added continuous recorders for wind of his own design and building. This was first successfully tried at East Malling, where the equipment was set up at blossom time to help Dr. Rogers get a measure of air movement among apple-trees on nights of radiation frost. It was then used at Woburn along with a duplicate set of temperature and humidity recorders in a first attempt to find out what difference irrigation makes to the micro-climate of the crops irrigated. In this wet summer no differences were detected.

Transferred to Rothamsted potatoes in late summer, the wind recorders have usefully supplemented the other information about dew formation and vapour-pressure gradients. An account of this work was given at the Toronto Conference. Although there may be wide variations, a typical " dew " night has the following character : about sunset the wind drops quickly, the atmosphere in and above the crop is saturated, but there are vapour-pressure gradients such that vapour moves to the crop canopy from the air above and from the soil beneath. Condensation takes place at a fairly uniform rate until about sunrise, when there is a simultaneous rise in temperature and in wind speed, and a relatively rapid re-evaporation of the dew, completed in about 3 hours, the final phases of which coincide with a change from saturation to non-saturation in the ambient atmosphere.

Heat flow in the soil

J. S. G. McCulloch has made an intensive study of the causes of the anomalies found in deriving thermal diffusivity from records of daily amplitude and daily phase of temperature waves in the soil. These anomalies are attributed to the variation of the " constant " with depth, and standard theory has been modified to take account of this variation with depth in a way that makes no initial assumptions about its form. The final expression for the diffusivity is essentially the same as one due to Dr. Peerlkamp of Holland, unknown to us until recently. The main immediate application of the new theory is in determining the effect of changes of water content on thermal constants of the soil.

Soil Physics

The effect of organic matter on crumb cohesion

Previous methods for measuring crumb cohesion, such as wet sieving, have not distinguished between the breakdown of crumbs on wetting, due to entrapped air (slaking), and that produced by subsequent mechanical dispersion of the wetted crumbs. From the previous year's work on the dependence of slaking on the rate of wetting, W. W. Emerson concluded that under the low intensity rainfall conditions prevailing in England, slaking would be a relatively unimportant cause of crumb breakdown.

A test was needed, therefore, which would measure only the resistance of crumbs to dispersion. It was found that natural soil crumbs, which are effectively calcium saturated, would not disperse in very low concentrations of calcium chloride unless mechanically disturbed. This accounts for the dependence of the results obtained by wet sieving on the particular way in which the sieves are agitated. However, if the soil crumbs are sodium saturated, swelling and then dispersion occur spontaneously as the crumbs are flushed with successively lower concentrations of sodium chloride. The degree of dispersion at any particular concentration is an index of the stability of the crumbs.

This technique has been used to study soil samples taken from grass and lucerne plots laid out on a field which had been in arable cultivation for many years. This soil contains calcium carbonate. Two to four years under grass have materially increased the cohesion of the surface crumbs compared with crumbs from adjoining fallow strips. As might be expected from the preponderance of roots in the surface layers, the improvement in soil cohesion is much greater at 0–4 inches compared with the deeper soil layers.

The practical importance of increased crumb cohesion has still to be evaluated. *A priori*, less panning of the surface soil should occur, leading to better germination and growth due to improved root aeration. The four-year-old plots have been ploughed, and the growth of crops on these and the fallow strips will be compared.

Delayed swelling

Soil crumbs dried initially to the wilting point have been slowly percolated with $1 \times 10^{-2}M.$ calcium chloride through a capillary siphon. It has been shown by weighing the crumb at intervals that

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although excess solution is discharged from its base, after the first or second day the crumb continues to take up solution at a decreasing rate over the next three months. This is attributed to the rearrangement of the individual clay crystals, as the thickness of the water films on the crystals increases with decreasing suction. It has been shown theoretically that the equilibrium thickness of these films will increase markedly as the suction approaches zero.

The slow swelling of the clay will be accompanied by a corresponding decrease in the permeability of the crumbs as the larger pores are reduced in size. This is of great practical importance in the drainage of heavy clay soils, since it means that the permeability of the soil as a whole may be improved over the winter by using a deep-rooted crop to dry the subsoil out during the summer. This has been shown by comparing the drainage records of three fields : one after fallow, one after winter wheat and the third in permanent grass on the Gault of the Cambridge University Farm for the winter of 1932–33. It was also possible to infer from the dates at which the drains started running and the volume of water discharged that considerable delayed water uptake occurs as the clay slowly swells.

Delayed swelling also affects the concept of field capacity, since the moisture content of the soil at " field capacity " will increase during the winter with each succeeding fall of rain. Penman's * attempt to forecast the running of mole drains has been re-examined in this light.

The time taken for clay to swell partly explains why mole draining is successful at all and why it is preferable to mole in the spring rather than in the autumn. The gradual reduction in the cohesion of crumbs as the clay slowly swells may be important in some engineering problems.

Positive charges on the edge faces of clay crystals

G. H. Cashen has endeavoured to get further evidence for the existence of positive charges on the edge faces of clay crystals. Schofield and Samson (1953) gave reasons for thinking that at least a part of the buffer action of kaolinite is due to proton transfer at the edge faces. In order to accentuate the influence of the positive charges, the effect of the larger negative charges associated with the cleavage faces has been progressively suppressed by the addition of graded amounts of an organic cation (*cetyl trimethyl* ammonium). In this way the normal lowering of pH when KCl is added to a clay suspension has been reversed. The results are not yet entirely satisfactory owing to a troublesome drift in the pH values.

Physical Chemistry

Soil tests for flooded land

A. W. Taylor has worked out the details of a method devised by R. K. Schofield for measuring the deficit of divalent ions in a soil which has been flooded by sea-water. This method (modified slightly for convenience in routine testing) will be used by the National Agricultural Advisory Service to test heavy land which may require more than the standard dressings of gypsum in order to prevent breakdown of structure during the next few years.

* *J. Soil Sci.* (1949), **1**, 74–89.

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Many soil samples were taken by N.A.A.S. officers from the land after the flooding, and the chloride contents of these samples were determined in N.A.A.S. laboratories. This information was of considerable value as a guide to the chances of successful cropping in 1953 when plant growth was mainly affected by the salt content of the soil. In a general way it was to be expected that high salt content would run parallel with the degree of replacement of divalent cations by sodium which, if not corrected by application of gypsum, would ultimately result in loss of soil structure. Provision was therefore made for the application of 2 tons per acre of gypsum to all arable land containing more than 0·1 per cent of sodium chloride in the top 6 inches.

It was believed that this gypsum dressing would be sufficient to safeguard the structure of considerable areas, but that more would subsequently be required on some of the heavy lands. A test was needed that would, in effect, determine the amount of exchangeable sodium, but no satisfactory laboratory method was available.

Although the development of the flame photometer has revolutionized the determination of sodium, the difficulty is to determine how much of the total sodium in the soil sample is present as salt, which in itself is no danger to soil structure, and how much is present as exchangeable sodium, which is potentially injurious.

A practical solution to the problem has been found through measuring the quantity of divalent ions which the soil sample can *take up* rather than the sodium given out in the exchange reaction. It is logical to recommend a field application of gypsum equivalent to the amount which can be seen to react with the soil sample under laboratory conditions. Moreover, since field conditions are never as favourable for complete reaction as those which can be arranged in the laboratory, this method of test will tend to underestimate the amount of gypsum which could give maximum benefit in the field. Furthermore, in calculating the field dressing a somewhat arbitrary figure must be taken for the depth to which it is considered necessary for the reaction to proceed.

In spite of these obvious limitations, it is hoped that the test will prove useful.

Soil solution equilibrium

The acquisition of a flame photometer has greatly facilitated the determination of K and Na at low concentrations, while the development and refinement of the versenate titration has facilitated the estimation of Ca and Mg. A critical examination of the soil/solution equilibrium, which was formerly impracticable, is now under way.