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Physics Department

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PHYSICS DEPARTMENT

By R. K. SCHOFIELD

Two vacancies, one caused by the appointment of Dr. B. A. Keen to the directorship of the East African Agriculture and Forestry Research Organization and the subsequent appointment of Dr. R. K. Schofield to the headship of the department, and the other caused by the appointment of Dr. E. W. Russell to the readership in soil science at Oxford, have been filled during the year. Dr. W. C. A. Hutchinson took up his appointment in September and has since been working with Dr. H. L. Penman in the field of agricultural meteorology. Mr. W. W. Emerson started in October to take up the general lines of work related to soil cultivation developed by Dr. Russell. Mr. A. W. Taylor also joined the department in October under a special grant from the Agricultural Research Council to work directly under Dr. Schofield in a study of the chemical potentials of ions in soil. At the beginning of the year Mr. P. C. Owen transferred to the Botany Department.

Dr. M. L. Puri completed his period as a voluntary worker and obtained the Ph.D. degree of London University. Mr. H. C. Aslyng continued as a British Council Scholar, and in December was appointed Reader in Soil Science at the Royal Veterinary and Agricultural College at Copenhagen.

Dr. Schofield has served on the Joint Committee on Soils appointed jointly by the Department of Scientific and Industrial Research and the Ministry of Supply. Dr. Schofield and Dr. Penman are both members of the Technical Panel of the Land Drainage Legislation Sub-Committee of the Ministry of Agriculture's Central Advisory Water Committee. Dr. Penman served on the Council of the Royal Meteorological Society and on the Board of the Institute of Physics. During July he visited Holland and lectured to the Hydrology Commission of the Dutch T.N.O. on Rothamsted researches on evaporation.

SOIL CULTIVATION

Deep ploughing

The loss of Dr. Russell and the transfer of Mr. Owen, who had assisted him in the deep ploughing work, have restricted operations this year to the continuation of the six-course experiment at Rothamsted.

The plots which were deep ploughed this year have now been deep ploughed three times. The soil to plough depth is now well mixed, but there is little colour difference between the shallow and deep-ploughed plots. The only noticeable difference is the greater stickiness of the soil in the deep-ploughed plots.

As in previous years, the germination and growth of sugar beet was slower on the deep-ploughed plots, but the difference had disappeared by June. At harvest, the deep-ploughed plots yielded 9.2 tons per acre of clean beet, while the shallow ploughed plots yielded 8.6 tons per acre. Deep incorporation of phosphate gave an advantage of 0.9 tons per acre. A similar effect was found each year since 1944 except 1948. As before, deep incorporation of potash was without effect.

Deep ploughing produced an increase in yield of potatoes from 5.7 to 6.7 tons per acre when potash was applied in the bouts. This can be accepted as a definite result for this site since it has occurred every year from the inception of the experiment in 1944 ; but no result of comparable consistency has yet been obtained at any outside centre.

The yield of wheat was again up by 1 cwt. per acre on the deep-ploughed plots. This advantage, though small, appears to be significant.

AGRICULTURAL METEOROLOGY

General

In a discussion on meteorology in agriculture, organized by the Royal Meteorological Society, the department supplied an introductory survey showing the type of statistical, biological and physical problems demanding solution. An account of the 1948 irrigation experiment was given to illustrate the possibility of estimating crop transpiration from measurements of weather factors. The Agricultural Meteorology Branch of the Meteorological Office (M.O. 19) is showing an encouraging interest which will probably take a practical form during 1950 when M.O. 19 hopes to issue monthly estimates of transpiration to the provincial centres of the National Agricultural Advisory Service.

Measurements of evaporation and drainage

Day to day measurements of evaporation from open water, bare soil and turf have been continued, and in the late summer apparatus was successfully designed to obtain continuous records. The records obtained for the open water surface generally show clearly the day maximum and the night minimum, but there are some anomalies, probably caused by differential thermal expansion of instrument components. The same apparatus, used to record the fluctuation of a water-table 2ft. below a turfed sandy soil, has given some details of the slow drainage referred to in 1948. Records show quite clearly that this drainage begins about sunrise and continues until nearly midday when the direction of movement of water is reversed as the effect of transpiration begins to dominate the flow.

Taking advantage of the dry summer, new copings have been fitted to the drain-gauges of Lawes and Gilbert, and slates on one wall of the 40-inch gauge have been renewed in the hope of stopping the leak discovered in 1940. Since the operation the drainage totals (November–December) have been :—20, 6.9 inches ; 40, 6.7 inches ; 60, 6.3 inches. The drainage from the 40-inch gauge is now less than that from the 20-inch gauge, as it should be, but is still not as close to that from the 60-inch gauge as might be expected.

Control of irrigation by calculation of soil moisture deficit from meteorological data

Two centres were in use in 1949. On Mr. F. Secrett's farm at Milford there were four watering treatments :—unirrigated control (0), full irrigation at Mr. Secrett's discretion (F), and two restricted treatments (R and M) based on weather data collected on the site. Treatment R was designed to permit the building up of a water deficit of $1\frac{1}{2}$ inches by the end of August, and was the same as in 1948 : treatment M was designed to permit an end-of-August

deficit of 3 inches. On the farm of Messrs. W. O. and P. O. Jolly at Kesgrave, Ipswich, there were three treatments :—O and M as at Milford, and a third (J) determined by Mr. Jolly. The summer was very dry, the May to August rain being 4.4 inches at Milford and 4.7 inches at Kesgrave, and irrigation operations were frequent. At Milford, treatment F took 13.1 inches in nine applications, R took 8.4 inches in six, and M took 6.5 inches in five ; at Kesgrave, J took 4.1 inches in two, and M took 5.6 inches in four applications.

The summer was characterized by a severe attack of virus disease, low sugar percentages, and a curious interaction of watering and nitrogen treatments, of which there were four at Milford and three at Kesgrave. As the lowest and highest were common to both centres, values for these are given in the following table :—

Yield of sugar (cwt. per acre)

Treatment	O	M	R	F	O	J	M
Irrigation (I) ...	0	6.5	8.5	13	0	4	5.5
Rain + I. (in.) ...	4.5	11	13	17.5	4.5	8.5	10
Yield { 0.4 cwt.N/a	36.0	44.3	44.2	44.1	30.2	49.8	53.6
{ 1.3 cwt.N/a	32.1	40.8	43.0	39.2	31.4	42.7	44.3

The results show the benefit of irrigation in a dry summer even for a deep-rooted crop like sugar beet. The benefit was greatest for the treatment based on weather data.

Rainfall, evaporation and run-off for the Stour Catchment

The Land Drainage Legislation Sub-committee of the Central Advisory Water Committee of the Ministry of Agriculture is gathering information through its technical Panel on the effects of land drainage on the flow of rivers. As a part of this inquiry Dr. Penman has examined the records of rainfall and run-off for the Stour Catchment over the period 1933 to 1948. On calculating the evaporation from mean values of meteorological observations taken at nearby stations he has accounted very satisfactorily for the difference between rainfall and run-off and for the changes in ground-water storage as exhibited by well records. Land drainage has been extensively carried out in this area since 1939 but it has been without discernible effect on the evaporation, and so cannot be said to have influenced the total amount of water discharged into the Stour.

Heat balance of the soil

Evaporation requires latent heat and this heat is a major item in the balance sheet of incoming and outgoing energy. The data for the Stour Catchment have been studied from this angle also. The results, which can be considered to apply to much of Southern England, show how incoming solar radiation is used up month by month throughout the year. Before and after the midsummer peak about half of the energy is used in evaporation (transpiration), and only small amounts are used in warming of the soil and the air. Throughout the year there is a fairly steady outward flow of long-wave radiation which, in winter, draws its energy from the soil and air.

In preparation for more detailed studies of heat flow in the soil, a set of resistance thermometers linked with automatic recording apparatus have been installed, which will measure the soil temperature down to 6 feet. It is hoped that the data thus accumulated will help to unravel the complex physics of radiation frosts.

Micrometeorology

The thermistor bridge, described in 1948, has been greatly used by Dr. Broadbent to obtain records of temperature and humidity profiles, and of wind speed among potato crops of varied spacing over dry and wet soil.

LABORATORY WORK

Measurement of the volumes of solids, water and air in soil clods

It has been necessary to make further minor modifications in the method introduced by Russell for measuring the volumes of solids, water and air in soil clods. Using the original technique it is impossible to prevent evaporation of water from the clod during the series of manipulations, and it is difficult to estimate the errors this may cause. A redesign of the apparatus practically eliminates this source of error. Further tests will be carried out.

Vapour pressure of aqueous solutions

It has been difficult to decide which set of measurements to take as the standard for accurate evaluation of aqueous vapour pressures. Between 98 per cent. relative vapour pressure and saturation—the range of greatest significance in soil and plant studies—the values for solutions of NaCl and KCl should be obtained very accurately from measurements of the E.M.F. of concentration cells. Direct vapour pressure measurements have not yet been made with sufficient accuracy to serve as a check, but there are numerous published results giving the concentrations of isopiestic solutions with high precision. A comparison shows that either the E.M.F. values for NaCl or those for KCl must be less exact than their internal consistency would lead one to expect, and a search is being made for a criterion that will reveal which set of data is the more reliable.

Provisionally the E.M.F. measurements for NaCl are being used in preference to those for KCl, and tables have been drawn up relating the molality of NaCl solutions to vertical height in metres, which express the amount by which the potential of water in the solution is lower than that of pure water at the same temperature. These tables are being used in the study of environmental factors influencing seed germination which the Botany Department is carrying out with the co-operation of the Physics Department. Careful consideration has been given to the design of the temperature regulators of the double thermostat tank used for this work. The apparatus is very satisfactory in that no short period temperature fluctuation that would disturb the relative vapour pressure of the seeds' environment can be detected with a thermometer sensitive to 0.001°C.

Thickness of water films

An apparatus for the measurement of the thickness of water films on mica was set up and some preliminary work carried out. Following the Russian work, a hydrogen bubble is pressed against a mica plate immersed in a solution of an electrolyte. The thickness of the phase film over the area of "contact" of the bubble is estimated by comparison of its light transmission with that of the surrounding Newton ring system. The comparison can be made directly by means of a suitable light-sensitive cell mounted on a travelling microscope. Owing to the lack of a suitable microscope

the method now being tried is a photographic one, which should at least have one advantage in giving a permanent record of each experiment. The necessary comparisons of the light intensities can be found by using a micro-photometer, and the bubble size by direct measurements on the photographic plate.

Thermodynamic potentials of soil constituents

Considerable progress has been made in the development of methods for determining the thermodynamic potentials of nutrients and other substances in soils. Where, as in soil, we are dealing with electrically charged particles it is difficult to define the potential of any single ionic constituent. We can, however, define the difference of potential between electrically equivalent quantities of two cationic or of two anionic components, or the sum of the potentials of electrically equivalent quantities of two components, one cationic and the other anionic. Thus the pH of a soil suspension is not, in itself, a characteristic of the soil, inasmuch as it depends on the salt concentration, whether set up merely as a consequence of shaking up a soil sample in distilled water, or deliberately produced by the addition of CaCl_2 . On the other hand, the difference of potential expressed by $\text{pH} - \frac{1}{2}\text{pCa}$ has a definite value for a soil sample independent of salt concentration up to about N/50. We expect this principle to apply to any pair of cations, and one of the tasks ahead is to demonstrate this.

Particular attention has been paid to phosphate, and it has been found that the potential sum represented by $\frac{1}{2}\text{pCa} + \text{pH}_2\text{PO}_4$ is independent of CaCl_2 concentration up to 0.01 molar. Values so far obtained range from 5.5 for soils liberally dressed with superphosphate to 8.5 for soils on which all crops fail unless phosphate is applied. Fortunately these potentials can be rapidly determined, and it is hoped that they will provide a surer basis for advice on phosphate manuring than any of the conventional methods hitherto employed.