ROTHAMSTED RESEARCH

Report for 1954

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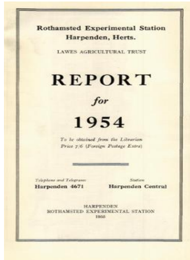
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Harpenden, Herts.
LAWES AGRICULTURAL TRUST
REPORT
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Physics Department

R. K. Schofield and H. L. Penman

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PHYSICS DEPARTMENT

R. K. SCHOFIELD & H. L. PENMAN

On 1 October 1954, R. K. Schofield was given charge of the Chemistry Department, and H. L. Penman became head of the Physics Department. This report reflects the old order, and falls into the same three parts as formerly.

J. S. G. McCulloch completed his research, supported by an Agricultural Research Council grant, and after a period with the Ministry of Supply will join the staff of the East African Agricultural and Forestry Research Organization in Kenya. F. Silva, of Colombia, has returned home. Short period visitors included Professor C. Manil, from Gembloux, Belgium, Miss Joan Whitmore, from Pretoria, South Africa, Mr. D. E. Patterson, from Leeds University, and Mr. L. E. Danfors, from Uppsala, Sweden. Mr. P. B. Flegg and Miss I. I. Warman from the Mushroom Research Station are working in the department until their new laboratories are ready.

W. W. Emerson and A. W. Taylor received the Ph.D. degree of London University. The latter was awarded a post-doctorate fellowship and is spending eight months at the University of Wisconsin, Madison. H. L. Penman attended the tenth general assembly of the International Union of Geodesy and Geophysics held in Rome.

AGRICULTURAL METEOROLOGY

Irrigation and evaporation—General

The Technical Bulletin (referred to in the Report of Rothamsted Experimental Station for 1952) on calculation of irrigation need was published during 1954. This and the results of the first sugar beet experiments and of the Woburn experiment have provided the basis for a number of articles, lectures and overseas broadcasts, and also for a British Association discussion on control of water for increased crop production.

At the request of the Institution of Water Engineers the paper on evaporation over the British Isles (*Quart. J. R. met. Soc.*, 1950, **76**, 372–383; *Rep. Rothamst. exp. Stat. for 1950*, p. 158) was reprinted in their *Transactions*. As a result of the publication of the first report from Lake Hefner, some minor changes have been made in the empirical formulae on which the calculations of potential transpiration are based, the effect of the changes being a reduction of about 5 per cent in estimated values. The revised formulae have been used in calculating values for an evaporation map of parts of Europe (presented to the International Union of Geodesy and Geophysics in Rome) in which the main new physical factor is snow cover for several months in some places. Agreement between evaporation as calculated and as estimated from catchment data was fairly good.

Some of the available data for the Thames Catchment (Report of Rothamsted Experimental Station for 1951) have been re-analysed to show the relative phases and amplitudes of the components in the water balance of the catchment. As a measure of the continuing inadequacy of estimates of evaporation, it is noted that uncertainty in monthly summer values exceeds the monthly summer discharge of the river.

Irrigation—Woburn

There is a new cropping system.

Grass. The old plots were ploughed up in 1953 and re-seeded with a pure grass strain (S 37 Cocksfoot) in April 1954. Germination was very poor because of drought, and on 13 May all plots were irrigated to save the crop. Subsequent growth was slow because of low temperatures and little sunshine, but by August there was a good stand of grass to provide adequate working material for 1955 and 1956.

Potatoes. Main crop potatoes replaced earlies.

Sugar beet and barley. No change.

The summer of 1954 has been the worst for irrigation since experiments started. Though April was very dry with less than a quarter inch of rain, thereafter rain days were very frequent, so that only in late June and early July was transpiration markedly in excess of rainfall. As a result of watering in that period and subsequent rain, many of the watered plots were maintained at field capacity from mid-July onward with periods of waterlogging and through drainage. The effect of this excess of water appears in the crop yields.

Woburn Irrigation 1954

Crop	Period	Rain (in.)	Irrigation (in.)	Plot		Yield
Grass	17 May–13 Sept.	10·8	0·5	ON_1	26·2	Dry matter (last 3 cuts), cwt./acre
				ON_2	38·8	
			2·9	CN_1	24·0	
				CN_2	35·2	
Sugar Beet	29 Apr.–27 Sept.	12·9	—	ON_1	40·9	Sugar, cwt./acre
				ON_2	49·6	
			1·2	CN_1	43·4	
				CN_2	46·1	
Barley	29 Apr.–19 July	7·8	—	ON_1	31·3	Grain, cwt./acre
				ON_2	36·8	
			1·8	CN_1	33·1	
				CN_2	36·0	
Potatoes	29 Apr.–27 Sept.	12·9	—	ON_1	14·0	tons/acre
				ON_2	17·9	
			2·2	CN_1	13·3	
				CN_2	16·9	

Detailed comment is unnecessary. Broadly the irrigation (all before the end of July) has led to slight decreases in yield—a valuable warning.

Micro-meteorology (I. F. Long and J. L. Monteith)

A second set of equipment has been built for continuous recording of air temperature, wet-bulb temperature and wind speed at several heights. After trouble with thermistors, Long has constructed small resistance thermometers of fine-gauge nickel wire, and these have proved so satisfactory in use that small recorded wet-bulb depressions can be relied upon with more certainty than before. He has also devised a transparent scale so that relative humidity and dew-point temperature can be read quickly from the charts.

One of the recorders has been in the sugar beet of the irrigation experiment at Woburn, but only in one short period has it been reasonable to expect any difference between irrigated plots and non-irrigated plots. The difference was clearly detected, the plot irrigated some days before having a damper, cooler atmosphere within the crop, but no detectable difference above the crop.

The second recorder has been in the Rothamsted potato plots used by J. M. Hirst for his potato blight studies. In addition to Hirst's dew balance, J. L. Monteith has set up a different kind of balance carrying a complete potato plant in soil, continuously weighed: with the balances is equipment for measuring temperature, humidity and wind velocity profiles as supplement to that used by Long. Detail is finer, but is necessarily confined to short periods on chosen nights.

Already it is clear that there are important differences in the dew formation on grass and on potatoes. Monteith's measurements over short grass at Harlington show that on dew nights the soil surface may be about 4° C. warmer than the air at 1 cm. above in the grass cover, and that much of the liquid found on the grass has distilled from the soil surface. Only on rare occasions have the vapour pressure gradients and wind velocities been sufficient to transfer appreciable amounts of water vapour to the leaves from the air above the grass.

For potatoes, where the main cooled surfaces are at the top of a leaf canopy 30–60 cm. above the soil, the vapour pressure gradients within the crop at night are very much smaller than in grass, so that upward distillation is probably negligible. On the other hand, the taller crop projects into a region of greater turbulence, and the possibility of downward transport of vapour is much greater. At present, the rough indication is that the maximum rates of dew formation are about the same on grass as on potatoes at about 3 mg./hr./cm.^{2} of underlying surface. As the condensation rates are an order of magnitude less than those of evaporation on days of moderate sunshine, it is unlikely that dew contributes significantly to the water resources of the growing crop.

Soil Physics

(*a*) Soil structure (W. W. Emerson)

Synthetic soil conditioners

The new sodium saturation test for soil stability (Report of Rothamsted Experimental Station for 1953) has been applied to measure the increase in crumb cohesion induced by the addition of various high-molecular-weight substances. Soils for testing have been taken from farm plots that have been continuously cropped without either manure or fertilizer for 80 years, one being acid (pH 5·3) and the other calcareous (pH 7·2). Natural structure was very poor.

Of the chemical compounds tested, some, such as casein and egg albumin, made the crumbs very difficult to wet, but produced no increase in crumb stability. Others gave positive increases, and

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four have been examined in detail: sodium alginate, polyvinyl alcohol, polyacrylic acid, and a co-polymer of vinyl acetate and maleic acid (Krilium CRD-186).

Sodium alginate was found to be effective only if the soil was first sodium saturated. It is presumed that attachment to the soil was prevented in the presence of calcium by the precipitation of the alginate as calcium alginate. The calcareous soil was completely stabilized, the crumbs remaining permeable to distilled water, by the addition of 0·2 per cent by weight of the four polymers to the soil. CRD-186 was even more efficient on the acid soil, stabilization being induced at 0·02 per cent by weight. This accords with field experiments with CRD-186, where the only visible effect on soil structure has been on the acid fields, and not on those containing free $CaCO_3$. The quantity of polyvinyl alcohol needed to stabilize the acid soil was 0·1 per cent by weight.

The mechanism of crumb stabilization is being studied. A previous suggestion of calcium ion " bridges " may be discarded, as the polymers are equally effective when only sodium ions are present. It has been found that the polyvinyl alcohol forms inter-planar compounds with the clay. The other polymers may act differently, possibly being linked by hydrogen bonds to the hydroxyl and oxygen atoms exposed along the edge faces of the clay crystals.

Soil structure field experiment

The four-years-old grass and lucerne plots, ploughed in the autumn of 1953, were sown to spring beans. There were very large differences in yield between these plots and those previously fallow, but there were also large differences in potash status. Similar comparisons for 1954/55 will include an attempt to remedy the potash inequality before the beans are sown.

The effect of liming on crumb cohesion

It has been found that natural crumbs from mildly acid Rothamsted fields are much more stable than those from fields containing free $CaCO_3$. This suggests that a given amount of organic matter is more effective under acid conditions, in agreement with laboratory results for CRD-186.

If the crumbs *are* dispersed by mechanical action, reflocculation can be induced by $CaCl_2$ at a concentration of $2 \times 10^{-3}M$, which is virtually independent of pH. In the field, in the presence of free $CaCO_3$, the concentration of CO_2 in the soil atmosphere will normally maintain a Ca^{++} concentration higher than this in the soil solution. Hence any dispersed clay will be more easily reflocculated in a calcareous soil.

Double-layer theory

The Gouy–Chapman theory has been extended. Previously it has been worked out to give the repulsive force between similar charged plates in a symmetrical electrolyte (e.g., both ions monovalent, or both divalent). The equations have now been solved exactly for 1 : 2 and 2 : 1 electrolytes, and numerically for all other cases. The corresponding attractive forces for oppositely charged plates have been evaluated for symmetrical electrolytes.

(*b*) Clay crystal structure (G. H. Cashen)

Positive charges on the edge faces

The work on kaolin has been continued. The method used attempts to mask the negative isomorphous charge by large organic cations (cetyl trimethyl ammonium) which are adsorbed on the cleavage faces : in the acid range, therefore, any pH changes occurring on addition of a neutral salt to the suspensions should be governed by the positive charges on the edge faces, i.e., a rise in pH should be obtained if there are positive charges present. Previous results were unreliable because of a drift in pH, most marked with those samples of kaolin considered to be most carefully purified, but efforts to find the causes of the instability have met some success. Two changes in technique—the use of polythene containers, which has eliminated contamination by traces of alkali from glass, and the use of highly concentrated suspensions—have together cut the drift down to a very small scale. The positive changes in pH on adding salt to acid kaolin suspensions can now be measured with some confidence, and confirm the existence of positive charges on the kaolin crystals in acid suspensions. The increase is about 0·2 pH units, and is largely independent of the nature of the pre-treatment of the samples of kaolin so far examined.

As the working pH is increased there comes a value sufficiently alkaline for the edge face charges to be negative, and then addition of salt causes a decrease in pH value. An analogous transition value can also be found for a change in adsorption of chloride ions as the pH is altered. The transition pH is higher for the chloride method : an explanation of the discrepancy is being sought.

Physical Chemistry

(A. W. Taylor and F. Silva)

The flame photometer (for potassium) and the versenate titration (for calcium and magnesium) have been used to determine the concentration of ions in solutions in equilibrium with soil samples for total concentrations of chlorides ranging from 1 to 50 $\times$ 10^{-3} normal. The results show that the activity of the magnesium ion varies directly as the activity of the calcium ion, whereas the activity of the potassium ion varies as the square root of the activity of the calcium ion. The relative concentrations of calcium and potassium were found to depend on temperature, a higher proportion of potassium being found at higher temperatures.

A simple and rapid test has been used to detect inequalities in the potash status of different plots of a field. A 25-g. sample of the soil is shaken for one hour with 50 ml. of 0·01M-$CaCl_2$ solution, filtered, and then the potassium concentration in the filtrate is determined. The concentrations given by soils from different plots on the Rothamsted farm vary from 5×10^{-5} to 2×10^{-3}, and show residual effects from potassium salts and dung applied as much as seventy years ago.

There has been further investigation of the very small concentrations of phosphate ions brought into solution when soil samples are shaken with $0{\cdot}01M$-$CaCl_2$ solution. The concentrations are not as reproducible as could be desired, and tend to diminish when the solution remains in contact with the soil for several days. This matter still needs further study.

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