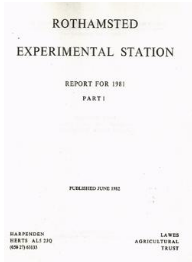
Report for 1981 - Part 1

Full Table of Content


ROTHAMSTED
EXPERIMENTAL STATION
REPORT FOR 1981
PART I

Physics Department

T. Woodhead

T. Woodhead (1982) *Physics Department ;* Report For 1981 - Part 1, pp 175 - 184 **- DOI: https://doi.org/10.23637/ERADOC-1-128**

PHYSICS DEPARTMENT

T. WOODHEAD

Staff

Head of Department T. Woodhead, PH.D.

Principal Scientific Officers
J. A. Currie, PH.D.
W. Day, PH.D.
B. J. Legg, PH.D.
G. D. Towner, PH.D.
E. G. Youngs, SC.D.

Senior Scientific Officers
N. J. Brown, M.I.AGR.E.
B. K French
H. A. McCartney, PH.D.
P. F. North, PH.D.
K. J. Parkinson, PH.D.

Higher Scientific Officers
R. Cuminetti, PH.D.
A. T. Day
J. E. Leach, PH.D.
D. T. Pritchard
R. P. Scammell, PH.D.

Scientific Officer
J. Croft

Assistant Scientific Officers
A. G. Dailey
Miss Gillian Dawes, B.SC.
Miss Corinne J. Quayle
N. R. Shah

Students
D. Connor
C. H. Wells

Personal Secretary
Mrs Ann E. Roberts

Typist
Mrs Jennifer H. Large

Introduction

1981 was for the Physics Department a year in which much effort was devoted to developing and testing mathematical models of various plant and soil processes. In plant physics, several models were examined for their ability to describe detailed observations of the photosynthesis of single leaves that were made during a 1979 experiment on the effects of drought on spring barley (*Rothamsted Report for 1979*, Part 1, 159). The most suitable was a resistance-analogue model with four adjustable parameters. After slight adaptation, this model well fitted the 1979 data and gave good descriptions also for a series of laboratory measurements on wheat leaves. Using the model, it has been possible to quantify the effects of water stress and temperature on the four parameters, each of which has a basis in the known physiology of photosynthesis. In the same 1979 experiment the drought treatments had significant effects on the areas of the three leaves that appeared last on each main stem. Analysis by an appropriate growth model has shown that the differences result from differences in rates, rather than in durations, of leaf extension. In soil physics, a simulation model has been developed that improves precision in determining soil-water diffusivities from measurements of rates of water outflow from horizontal soil columns. And in new work, simulation models have been used also in layered-soil models of the diffusion of gases, and preliminary experiments have been undertaken to determine the representative minimum volume of a structured soil that can be considered homogeneous in models for processes such as the movement of water and nutrients to plant roots.

In soil research there was progress too in the improvement of equipment and measuring technique. Improved factors have been derived for correcting soil-water content readings made in the top 25 cm of soil by neutron moderation meters. To aid laboratory determi-

https://doi.org/10.23637/ERADOC-1-128

nations of soil-water characteristics, a new design of 1·5 MPa (15 bar) pressure plate apparatus has been drawn up; the design, prepared in collaboration with the Engineering and Maintenance Section, meets the stringent conditions imposed by the Health and Safety Act and will meet not only the Department's needs but also those of researchers in universities and other ARS institutes. For soil-water potential, analysis has demonstrated how the time response of *in situ* measurements by tensiometers may be shortened, and hence measurements made more frequently, by making a practicable and cheap modification to the tensiometer sensor. Work is proceeding also with development of a null-point tensiometer—such a device could find application in studies of water uptake by roots. For water potential in leaves, measurements have shown that the measuring procedure most commonly used can give results systematically in error by as much as 0·6 MPa; a new technique has been evolved to avoid the bias. Leaves' stomatal conductances for water vapour transfer were this year successfully measured and results displayed using porometers equipped with the microcomputers described in *Rothamsted Report for 1980*, Part 1, 168. The same *Report* (p. 166) referred to a larger computer system that supports research in aerobiology: that system has now been programmed and used to record windspeed and hence its turbulence at rates of up to 3000 measurements per second.

The aerobiology research was undertaken, as in previous years, in partnership with the Departments of Plant Pathology and Insecticides and Fungicides and with the Chemical Liaison Unit. The technique for measuring hydraulic conductivity on undisturbed monoliths of field soil, described in *Rothamsted Report for 1980*, Part 1, 172, has been successfully tested on soils of the Evesham series in collaborative experiments at the Letcombe Laboratory. Field studies of the influences of drill type and drilling speed on the emergence and growth of cereal plants have been undertaken jointly with Farms; the findings guided the September drilling of winter wheat plots upon which various drought treatments will be imposed in 1982. This latter experiment, pursued jointly with the Departments of Botany and Soils and Plant Nutrition, has been designed to integrate closely with the Station's multidisciplinary programme on winter wheat and with a four-institute exercise to model growth of that crop. In interdepartmental studies in 1981 the Department made several series of plant and soil measurements in experiments on the growth of winter wheat and of the response of spring barley to deep cultivation and fertilisation.

Soil Physics

Soil water

Hydraulic conductivity and soil-water diffusivity. Values for hydraulic conductivity for soils have long been sought and applied by agricultural land drainage designers. More recently, modellers of crop growth have also found need of such conductivity values.

For an application of this latter sort, measurements of conductivity have been made on the multidisciplinary winter wheat experiment at Woburn (p. 25) using the instantaneous profile method and the experimental techniques that were described in *Rothamsted Report for 1980*, Part 1, 169. A soil plot, 2·3 m square, was hydraulically isolated from its surrounds by a vertical sheet of polythene extending to 1·0 m depth; rainfall and surface runoff water were excluded by a polythene tent. The soil was wetted to saturation, and its surface then sealed. As the soil drained, simultaneous measurements of soil-water content and pressure were made at periodic intervals at various depths in the 0–50 cm soil layer. Preliminary observations are (i) that the soil at saturation could accept a surface infiltration rate of between 12 and 17 mm h^{-1}, and (ii) that even within a soil area so small as 2·3 m square, there was evidence of horizontal heterogeneity in soil structure large enough to make difficult the interpretation of measured values of saturated hydraulic conduc-

https://doi.org/10.23637/ERADOC-1-128

tivity. (Brown, North and Wilson, with Weir and Dimase, Soils and Plant Nutrition Department)

The same instantaneous profile method was used at Rothamsted in a 1980 experiment (*Rothamsted Report for 1980*, Part 1, 169) that aimed to quantify the effect on hydraulic conductivity of a tillage treatment comprising a tine cultivation followed by a deep harrowing. Compared to plots that had lain fallow and undisturbed for two years, plots subjected to the tillage treatment had a slower rate of drainage during the hours immediately following saturation. Thus, at 1·0 h after onset of drainage, soil-water flux at 25 cm depth on tilled and undisturbed plots was respectively ~ 2 and ~ 5 mm h^{-1}. At 24 h after onset, drainage fluxes were similar on all plots, at $\sim 0{\cdot}3$ mm h^{-1}, and 6 days later were $\sim 0{\cdot}05$ mm h^{-1}—at which time at 5 cm depth all pores having equivalent cylindrical diameter greater than 75 μm had drained. Gradients of hydraulic potential were smaller on tilled than on undisturbed plots, but were for all plots approximately constant throughout the depth of measurement, and showed less variation with time than did the fluxes. Hydraulic conductivity was much affected by the tillage treatment, and, notwithstanding the preliminary finding reported in *Rothamsted Report for 1980*, Part 1, 169, was at some water contents, and for comparisons at similar water contents, some ten times greater on undisturbed than on tilled plots. This unexpected effect, and effects on hydraulic conductivity described in a later section of this report, could result if the particular sequence of tine and harrow cultivations led to a filling of the tine-created large pores by the many small crumbs produced by the harrowing. (Brown, North and Cuminetti)

In some calculations of soil-water movement there can be advantage in using as a parameter the soil-water diffusivity, rather than the hydraulic conductivity; the two parameters relate the flux density of the water flow respectively to the soil-water content and to the soil-water potential. Both parameters are, in general, functions of water content. Diffusivities are often determined, through an approximate analysis due to Gardner (*Proceedings of Soil Science Society of America* (1962), **26**, 404), from measurements made on horizontal soil columns losing water from one end and sealed against loss at the other. Unfortunately, results can be in error by a factor of three. Other researchers have determined diffusivities through alternative analyses that have varying complexity and accuracy but limited applicability. A new appraisal of Gardner's original method has shown that results of higher accuracy can be obtained if the column measurements are supported by a numerical simulation of the water-content changes in a hypothetical column having the same dimensions as the real column. Thus, measurements of the changes with time of the water content of the real column are analysed by Gardner's method to give an approximate diffusivity value that can be interpreted as a mean value weighted according to the various water contents existing in the column at a specific time. This mean diffusivity can then be used both to determine a first approximation for values of diffusivity at various water contents— the diffusivity function—and to calculate through diffusion theory a set of simulated water contents for various distances along the hypothetical column. Gardner's analysis is then applied again, to these simulated values, thus giving a more accurate mean diffusivity, which can in turn be used to simulate more accurately the diffusivity function and the hypothetical water contents. The iteration is continued until simulated and measured water contents agree, whereat the last-determined diffusivity function is accepted as the most accurate that the measurements allow.

The method has been validated, using computer modelling of the experiments, for four assumed functions of diffusivity *v.* water content: two linear and two exponential, increasing and decreasing with water content. The procedure gave reliable results; moreover, the ability to cope with diffusivity functions that decrease with water content constitutes an improvement over other recent methods of analysis. The new method thus

https://doi.org/10.23637/ERADOC-1-128

brings improvements both in accuracy and in applicability, and will be found useful in various studies of soil-water movement. (Towner)

Measurement of soil-water content and pressure. At soil depths less than 25 cm, measurements by neutron moderation of soil-water content are subject to systematic error because of the depth- and water-content-dependent loss of neutrons to the atmosphere. The magnitude of the errors and their corresponding corrections are specific to each particular design of neutron moderation meter. For the meter that they designed and used at Rothamsted, Long and French (*Journal of Soil Science* (1967), **18,** 149–166) reported empirical corrections determined in the laboratory. Applications to the same meter of a field method for deriving the corrections was described in *Rothamsted Report for 1978*, Part 1, 202; measurements by that method, here reported, will be used in our soil physics and plant physics projects and will serve also to show how large the corrections may need to be for other designs of meter. Corrections were determined for fractional volumetric water contents ranging from 0·14 to 0·48 and at depths of 0, 5, 10, 15, 20 and 25 cm on soil plots comprising part of the Department's tillage experiment site. Correction factors, by which the uncorrected water content should be scaled to give the true water content, were found to relate almost linearly to water content at each of the six depths of measurement. Values appropriate to true water contents of 0·20, 0·30 and 0·45 are given for each depth of measurement in Table 1. Correction of a measured water content may thus be made with precision adequate for most purposes through a two-stage calculation: first, an approximate water content is determined by multiplying the uncorrected content by the correction factor listed in Table 1 for the depth of measurement and for a water content of 0·30 (representing an average water content); secondly, this approximate water content is used, interpolating between the entries in Table 1 for the measurement depth, to obtain a more specific correction factor by which the original measurement may be scaled. At 20 and 25 cm depth the factors do not change with water content, and only the first stage of calculation need be undertaken; below 25 cm the factors are unity. (North)

TABLE 1

Factors, as a function of soil depth and water content, that correct neutron scattering measurements of soil-water content for the effects of escape of neutrons to the atmosphere

(Uncorrected values of soil-water content as measured by the Long and French design of neutron scattering mositure meter should be *multiplied* by the tabulated factors to give the true volumetric water content)

	Fractional volumetric water content		
Depth/cm	0·20	0·30	0·45
0	11	10	8
5	2·0	2·0	1·9
10	1·27	1·26	1·25
15	1·06	1·04	1·03
20	1·02	1·02	1·02
25	1·01	1·01	1·01

For *in situ* measurements by tensiometer of soil-water pressure, the soil itself can be a major determinant of the time response of the soil/tensiometer system (refer Parts 1 of *Rothamsted Report for 1979*, p. 154, and *for 1980*, p. 172). Furthermore, although there are for such measurements distinct advantages in using as the pressure sensor an electrical pressure transducer, as opposed to a mercury manometer, one advantage, that of a rapid time response, may be lost if a single transducer is used to sense sequentially the suction in

https://doi.org/10.23637/ERADOC-1-128

several tensiometer cups. Theoretical analyses have been undertaken to determine whether the time response of sequentially scanned tensiometers can be shortened by connecting to each tensiometer cup a reservoir that deforms under pressure (as does the spiral of a Bourdon pressure gauge or the capsule of an aneroid gauge) but with a sensitivity to pressure that is less than that of an electrical transducer. Thus, during the major part of a scanning cycle, when a particular tensiometer cup and its attached reservoir are *not* connected to the pressure transducer, the cup and reservoir come almost into equilibrium with the pressure of the surrounding soil water. Consequently, the tensiometer and reservoir, when next connected to the transducer, cause the water pressure in the latter to move rapidly to a value close to the soil-water pressure, and hence to an acceptably accurate final reading, much more quickly than could be achieved without the reservoir. Calculations show that, using currently available hardware, the proposed method will improve the monitoring of soil-water pressure. (Towner)

Soil structure

Mole drainage. The hydraulic role of the cracks that are produced in a clay soil by a mole-plough blade are being investigated in association with the National College of Agricultural Engineering (*Rothamsted Report for 1979*, Part 1, 154). One effect of the mole-plough operation is to loosen the soil, therby increasing its hydraulic conductivity. The geometry of the zone of loosened soil depends on the type of mole-plough blade and its setting relative to the soil surface. With the assumption that hydraulic conductivity for the loosened soil is much greater than for the unloosened, potential theory has been applied to calculate drain performance for different geometries of disturbed zone. Results show that the more nearly is the disturbed zone rectangular, the more effective is the drain: a finding that gives scientific support for current trends in the design of mole-plough blades. (Youngs and Dailey)

Tillage. In a preceding section on soil-water physics, report was made of a 1980 tillage experiment in which treatment plots were subjected to deep tining plus deep power harrowing and control plots were left undisturbed for two years. Measurements from that experiment of profiles of thermal conductivity (*Rothamsted Report for 1980*, Part 1, 169) have now been analysed, and show that thermal conductivity can, for the same water content, be smaller by some 15–20% on tilled than on untilled plots: the difference probably resulting from changes in the relative proportions of solids and air. Effects of tillage on the pores available to soil water were such that at cessation of drainage tilled plots stored about 18% more water in the 0–25 cm layer than did undisturbed plots. For that same layer, and for both tilled and undisturbed plots, curves relating the *in situ* measurements of soil-water content and pressure were mathematically differentiated to give pore-size frequency distributions. The distribution for the tilled soil, as compared to that for the undisturbed soil, (i) showed a maximum shifted towards smaller diameters, and (ii) had, for pores larger than about 50 μm equivalent cylindrical diameter, a smaller total pore volume. These latter findings are qualitatively consistent with the earlier-reported effects on hydraulic conductivity. (North, Brown and Cuminetti)

Gaseous diffusion: accurate coefficients for diffusion of gases in air. Diffusivity, a measure of the ability of two gases to interdiffuse within a porous medium, can be used to characterise porous solids, such as soils. Such characterisations should be independent of the gases used, and diffusivity is therefore usually expressed as a fraction of the diffusion coefficient D_0 for the same pair of gases in the absence of a solid phase. In studies of soil aeration, the gas pairs of interest include air in combination with either carbon dioxide,

https://doi.org/10.23637/ERADOC-1-128

nitrous oxide, ethylene, or ethane. For these pairs, values for D_0 more accurate than those currently available have been determined using a new steady state method in which one gas (e.g. carbon dioxide) was introduced at a constant rate into one end of a tube through which it moved by mass flow and diffusion into a semi-infinite volume of air. Corrections were made for the effects of mass flow using an improved method that allowed for introduction of the test gas at concentrations less than 100%. This improvement confers four advantages: errors in the total flow rate are relatively unimportant, density gradients are small so that convection is inhibited, the gas analysis is more sensitive, and diffusion coefficients are measured at the small concentrations encountered in soils. The measured diffusion coefficients, in air, at STP, were respectively 0·139, 0·143, 0·137and 0·128 $cm^2 s^{-1}$ for carbon dioxide, nitrous oxide, ethylene and ethane respectively. These values are believed to be accurate to better than $\pm 2\%$. (Currie and Pritchard)

Plant physics

Response of cereals to water stress

Effects of deep cultivation: spring barley. Measurements of soil-water content and of leaf-water potential were made as part of a multidisciplinary study of the effects of cultivations, carried out in spring 1980, that disturbed the subsoil and incorporated P and K fertilisers to depth. Leaf-water potentials showed no significant effects of treatments. However, the crop, and the measurements, had such large within-treatment variability that between-treatment effects could not be sought with any precision. Experience of this crop and its variability was none the less useful in guiding experiments on crop establishment and on procedures for measuring leaf-water potential that are described later in this report. (Leach, French, Shah and W. Day)

Leaf growth: spring barley. In a 1979 experiment that investigated the effects on a spring barley crop of droughts of various intensities at different growth stages, the drought treatment imposed prior to anthesis caused significant differences in areas for each of the last three leaves to appear on the main stems (*Rothamsted Report for 1980*, Part 1, 167). Further analysis of the growth of the leaves on 75 main stems has shown that for leaves 5–9 the maximum lamina length was significantly affected by the treatments: as between plots fully irrigated and plots neither irrigated nor rainfed, maximum lengths for leaf 7 were respectively (251 ± 7) and (192 ± 7) mm, and for leaf 8 (226 ± 7) and (163 ± 7) mm; leaves 1–4 were not significantly affected by drought. Moreover, these differences in maximum length have been shown to result from differences in rates, rather than in durations, of extension. Other measurements have shown that the rate at which leaves appeared on the main stems was not affected by drought. Analysis of the growth of leaves on first and second tillers is now in progress—such tillers make a major contribution both to crop green leaf area and to harvestable grain. (Leach and W. Day)

Photosynthesis: spring barley. In the same 1979 experiment, measurements were made, throughout the growing season and on the different drought treatments, of the responses to irradiance and to carbon dioxide concentration of the photosynthesis rates of some 300 individual leaves and ears. Various mathematical models have been examined for their suitability to describe these data and some similar data obtained in growth-cabinet experiments. The field and cabinet studies included measurements of water vapour exchange, the results of which allowed calculation of the influences of changes in stomatal aperture on the substomatal concentrations of carbon dioxide; knowing these concentrations it was possible to test models that deal with processes of photosynthesis occurring between the substomatal cavities and the sites of fixation. Good descriptions

https://doi.org/10.23637/ERADOC-1-128

were achieved by two separate models: the physiologically based four-parameter resistance-analogue model of Chartier and Prioul (*Photosynthetica* (1976), **10**, 48–57), with some adaptation, well fitted the data; a five-parameter model, due to Farquhar, von Caemmerer and Berry (*Planta* (1980), **149**, 78–90) and founded in the photosynthetic biochemistry, gave a less close but none the less acceptable fit.

Using the resistance-analogue model, the 300 individual leaf and ear responses have been analysed. For the leaves, fitting of the model gave precise values for the model's four adjustable parameters, and hence of the effects on those parameters of the imposed water stress and also of the monitored leaf temperature. The individual parameters relate to quantum yield, mesophyll conductance for carbon dioxide transfer, and to rates of photorespiration and basal respiration (from non-photorespiratory processes occurring in the light). Results showed that quantum yield α, at $(0{\cdot}051 \pm 0{\cdot}003)$ mol Einstein^{-1}, was unaffected by water stress or leaf age or by leaf tempetature over the range 13–20°C: for temperatures between 20 and 30°C, α declined linearly by 0·003 mol Einstein^{-1} K^{-1}. Mesphyll conductance g_m did not change with temperature, and for all water stress treatments was constant at $(2{\cdot}3 \pm 0{\cdot}1)$ mm s^{-1} until some days after maximum leaf extension; on the most stressed treatment g_m decreased by 0·10 mm s^{-1} day^{-1} from 5 days after maximum leaf extension: on other treatments it remained at 2·3 mm s^{-1} until 15 days after maximum extension, whereafter it declined by 0·05 mm s^{-1} day^{-1}. Photorespiration, affected directly neither by water stress nor leaf age but only by temperature, increased for a 10 K rise in temperature by a factor (the Q_{10}) of $1{\cdot}2 \pm 0{\cdot}1$. Basal respiration rate R_D showed no direct effect of water stress, but did change with both leaf age and temperature: at the time of maximum leaf extension, average R_D at 20°C was $(0{\cdot}93 \pm 0{\cdot}04)$ μmol m^{-2} s^{-1}, with a Q_{10} of $1{\cdot}7 \pm 0{\cdot}2$, and, after maximum extension, decreased by 0·009 μmol m^{-2} s^{-1} day^{-1}. Data for ears were not well fitted by the four-parameter model: the measured responses to irradiance were more curved—in fact more nearly rectangular hyperbolae—than the model allowed. For ears, therefore, a different model was adopted, comprising essentially a rectangular hyperbola function—with parameters relating to quantum yield α and to a combined mesophyll/carboxylation conductance for carbon dioxide transfer—augmented by respiration parameters. The data were well fitted by this model. Results showed that for ears, in contrast to the findings for leaves, α was unaffected by temperature, but did decrease as water stress increased. The conductance parameter was constant, independent of temperature, ear age or water stress; photorespiration rate, as determined by this model for these data, was effectively zero. As with leaves, basal respiration for ears showed no direct effect of water stress, but did increase with temperature and decreased as ears aged.

Thus for those aspects of photosynthesis here analysed the only direct effects of water stress were on mesophyll conductance in leaves and quantum yield in ears. Temperature had more and larger influences—on quantum yield and photorespiration in leaves, and on basal respiration in both leaves and ears. However, in the field a water-stressed crop will be warmer and will mature and senesce earlier than a non-stressed one: water stress does therefore have indirect as well as direct effects on photosynthesis, and both types of effect must be accommodated in models for growth and yield of water-stressed crops. (Parkinson, W. Day and Dawes)

Light interception: winter wheat. Measurements pertaining to photosynthesis were a major component also of the Department's contribution to the multidisciplinary study at Woburn of factors limiting the yield of winter wheat (a full report of the experiment appears on p. 25). Dry matter harvest yield of a crop relates closely to the season's total of photosynthetically active radiation actually intercepted by the crop's green foliage (Monteith, *Philosophical Transactions of the Royal Society* (1977), **B 281**, 277–294). Thus

https://doi.org/10.23637/ERADOC-1-128

in the multifactorial study any imposed treatment likely to give a yield response would be likely to affect also the intercepted irradiance. This prediction was confirmed by measurements, made on all 32 of the experiment's factorial plots, that showed that intercepted irradiance (corrected for interception by non-green foliage) was indeed affected by differences in sowing date and in rates and timings of nitrogen fertiliser, by application of irrigation, and by interactions of these treatments. Moreover, for the 32 plots, grain yields at harvest correlated closely with the season's totals of green-foliage-intercepted irradiance. (W. Day and Shah, with Welbank, Botany Department, and others)

Measurement of leaf-water potential. Field studies of crop responses to irrigation and drought usually involve measurements by pressure chamber of leaf-water potential. The technique requires the excision of leaves prior to their placement in the chamber, and experiments here and elsewhere have shown that unless water loss from the excised leaf is prevented, results will be biased. For wheat and barley field-grown at Rothamsted, measurements showed that the bias varies diurnally and with soil-water status, and can be as large as 0·6 MPa (6 bar). Neither humidification of the chamber, nor storage of leaves in foil-lined bags after excision, nullified the bias: storage in moist bags—a common practice—did lessen it, though to a variable extent. A new technique has been developed to reduce the water loss and hence the bias: prior to excision the leaf is wrapped in plastic Clingfilm, and remains so wrapped in the chamber throughout the measurement process. The technique is effective and simple and convenient to use. (Leach, W. Day and Woodhead)

Crop establishment. A high uniformity of plant size and spacing is required in many field experiments—particularly in experiments, such as those under rain shelters, that are constrained to small plots. Tractor wheelings, especially, can be a source of non-uniformity in plant emergence and early growth. An investigation at Rothamsted has sought to determine therefore whether the type of seed drill, or of drill/cultivator combination, or the drill speed, have significant effects on crop uniformity, and whether in particular the effects of wheelings can be lessened by the use of a rotary cultivator between the tractor and drill. With spring barley as test crop, three drills were compared: a disc-coulter drill, a 'Fiona' drill with spring-tine coulters, and a 'Fiona' drill with Suffolk coulters—the latter used both with and without a 'Roterra' rotary cultivator. The 'Fiona' drills were used at each of three speeds. Performance in achieving uniformity of crop was assessed from counts of the numbers of emerged plants per 10 cm of row in 80 cm sections of each drilled row, and from measurements of mean depth of seed planted and, on selected plots, of plant dry matter in mid-June.

Drill speed had no significant effect on plant numbers, but at the highest speed the drill with spring-tine coulters planted the seeds less deeply. As between drills, final totals of emerged plants showed few differences; as to uniformity of plant emergence, our measure of *within-row* uniformity, the coefficient of variation of plant numbers in 10 cm lengths of row, was 53% for the spring-tine drill, 57% for the disc-coulter drill, and 62 and 65% for the Suffolk coulter drill respectively with and without the rotary cultivator. However, for variability *between* rows, coefficients of variation for plant numbers per 2·4 m length of row were 16% for the spring-tine drill, and 14 and 13% for the Suffolk coulter drill with and without the rotary cultivator; variability was not determined for the disc-coulter drill, for which performance was less intensively monitored. The larger variability for the spring-tine coulter drill resulted in part from one or two rows that had particularly poor totals of emerged plants. The mid-June plant samples, taken only from plots drilled at the intermediate speed (5 km h^{-1}), gave coefficients of variation for dry matter per 50 cm of row as 22% for the spring-tine and 30% for the Suffolk coulter drill both with and

https://doi.org/10.23637/ERADOC-1-128

without the 'Roterra'. (Measurements were not made for the disc-drilled plot.) Why the Suffolk coulter drill gave plants less uniform than did the spring-tine drill is not known: that the former sowed seeds to a depth of 4·0 cm, and the latter to 6·5 cm, is perhaps relevant. Tractor wheelings did not cause poor growth in this experiment, though they did so in spring barley crops in other experiments in 1981. On the basis primarily of the between-row variabilities, the choice was made that the Suffolk coulter drill with the rotary cultivator would be used for a 1981–82 rain-shelter study of the effects of drought on winter wheat. (W. Day and Leach, with Moffit, Farms)

Agricultural meteorology

Wind gusts and the lift-off from leaves of fungal spores. A 1980 experiment (*Rothamsted Report for 1980*, Part 1, 168) investigated the effect of wind speed on the lift-off from leaves and aluminium plates of spores of *Lycopodium* (club moss). It was concluded that for these simple spores in this particular idealised experiment the spores would not become airborne unless wind speed exceeded for a time of $\sim$0·1 s a specific threshold value. Experiments in 1981 investigated the more complicated and more realistic case of the lift-off of spores of barley mildew (*Erysiphe graminis*). Fast response anemometers were used to measure wind speed at three heights within a spring barley crop: results showed that gusts can have wind speeds as large as five times mean speed. Measurements of the aerial concentrations of the mildew spores are now being processed, and results will be analysed in conjunction with the wind speed data to determine whether there is for this natural system, as for the *Lycopodium*, a threshold wind speed for spore lift-off. (McCartney, Croft, A. T. Day and Quayle, with Bainbridge and Creighton, Plant Pathology Department)

Staff and visiting workers

W. Day left at the end of December, after 8 productive years in the Department, to take up the post of Head of the Environmental Physiology Section at Long Ashton Research Station. S. Wilson left in August to join the Post Office. R. P. Scammell joined the Department in December to work on models for crop growth, in a project funded by the European Economic Commission, and since January N. R. Shah has given assistance in the Department's contributions to multidisciplinary studies. R. J. Gummerson of Broom's Barn was attached to the soils and plant physics sections during February, and D. Connor and C. H. Wells each spent some months in the Depratment as sandwich course students.

B. J. Legg, whose study period at the CSIRO Division of Environmental Mechanics, Canberra, Australia, was extended for a second year, attended with W. Day the XIIIth International Botanical Congress in Sydney, Australia, Day speaking there and at Brisbane, Canberra, and Griffith in Australia and at Christchurch in New Zealand. E. G. Youngs gave a paper at the International Symposium on Rainfall: Runoff Modelling at Mississippi State University, USA, and visited also the University of Wisconsin and the Argonne Laboratory. Within Britain, several members of the Department presented papers and gave courses of lectures at various colleges, universities and conferences.

Publications

General Papers

1 Currie, J. A. (1980) Soil structure. In: *Soil: root relationships. Proceedings of Agricultural Science Seminar (London)*. London: ARC, pp. 23–28.

https://doi.org/10.23637/ERADOC-1-128

2 DAY, W. (1981) Water stress and crop growth. In: *Physiological processes limiting plant productivity*. London: Butterworths, pp. 199–215.

3 LEGG, B. J. (1981) Aerial environment and crop growth. In: *Mathematics and plant physiology*. London: Academic Press, pp. 129–149.

RESEARCH PAPERS

4 (AYLOR, D. E.), MCCARTNEY, H. A. & BAINBRIDGE, A. (1982) Deposition of particles liberated in gusts of wind. *Journal of Applied Meteorology* **20,** 1212–1221.

5 (CALLANDER, B. A.) & WOODHEAD, T. (1980) Eddy correlation measurements of convective heat flux and estimation of evaporative heat flux, over growing tea. *East African Agricultural and Forestry Journal* **43,** 85–101.

6 (LAW, R. M., HARRISON, R. M.), MCCARTNEY, H. A. (& TALENT, C. J. W.) (1982) Nitric oxide pollution in glasshouses. *Experimental Horticulture* **32,** 49–54.

7 MCCARTNEY, H. A., LEGG, B. J., BAINBRIDGE, A. & (JONES, C. D.) (1982) Electric charge and the deposition of spores of barley mildew *Erysiphe graminis*. *Atmospheric Environment* **16,** 1133–1144.

8 PARKINSON, K. J. (1981) An improved method for measuring soil respiration in the field. *Journal of Applied Ecology* **18,** 221–228.

9 PRITCHARD, D. T. & CURRIE, J. A. (1982) Diffusion coefficients of carbon dioxide, nitrous oxide, ethylene and ethane in air and their measurement. *Journal of Soil Science* **33,** 175–184.

10 TOWNER, G. D. (1981) The correction of *in situ* tensiometer readings for overburden pressures in swelling soils. *Journal of Soil Science* **32,** 499–504.

11 TOWNER, G. D. (1981) The response of tensiometers embedded in saturated soil peds of low hydraulic conductivity. *Journal of Agricultural Engineering Research* **26,** 541–549.

12 TOWNER, G. D. (1982) Towards more efficient soil-water modelling: moisture profiles for constant application or removal of water at the surface. *Journal of Agricultural Science, Cambridge* **98,** 437–445.

13 YOUNGS, E. G. (1982) The measurement of the variation with depth of the hydraulic conductivity of saturated soil monoliths. *Journal of Soil Science* **33,** 3–12.

14 YOUNGS, E. G. & PRICE, R. I. (1981) Scaling of infiltration behaviour in dissimilar porous materials. *Water Resources Research* **17,** 1065–1070.

https://doi.org/10.23637/ERADOC-1-128 *pp 11*