ROTHAMSTED RESEARCH

Report for 1975 - Part 1

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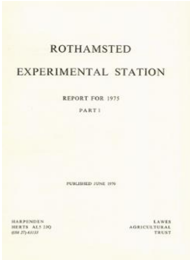

ROTHAMSTED
EXPERIMENTAL STATION
REPORT FOR 1975
PART 1

Physics Department

J. A. Currie

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The Department's work

In the physics department we are concerned primarily with the physical environment of the crop plant, endeavouring to measure and characterise those properties that would appear to determine plant growth. In the soil we consider the structure formed by the primary particles, measuring especially its stability, the way it influences the amounts and movement of water and air, and is in turn modified by cultivation practices. Above the ground we examine transfer processes for energy, momentum, carbon dioxide and water vapour both within and above the crop canopy. But whereas micrometeorology is essentially a subject where large experimental areas with adequate fetch are pre-requisites, we are now increasingly concerned with effects within the smaller plots we must use if we are to control rainfall using the mobile cover. It is difficult to separate the physics of the atmosphere from that of the plant, and our work necessarily makes an incursion via the stomata into the substomatal cavities of the leaves to examine the controlling mechanisms for assimilation and transpiration.

Soil structure. When a soil suspension is irradiated ultrasonically, it was shown last year (*Rothamsted Report for 1974*, Part 1, 202) that as the dispersive energy is increased there is an initial sharp increase in $<2\ \mu m$ particles in suspension but this amount subsequently becomes almost constant when dispersion is complete. For 1 g of soil the energy level at this point was selected as a specific stability index, σ (Jg^{-1}). Further measurements have been made this year on two groups of soils both obtained from the Soil Survey archives (Thomasson, *Memoirs, Soil Survey of England and Wales* (1971) Soils of the Melton Mowbray District). In group one 11 soils, from seven series, were chosen to have nearly constant clay content ($49 \pm 3\%$) but a range of organic carbon (0·7–8·3%). In group two, 12 soils from as many series were chosen to have similar organic carbon ($2{\cdot}6 \pm 0{\cdot}4\%$) but a range of clay content (16–59%). In group one, at near constant clay content, σ *increases* with organic carbon confirming the tentative suggestion made last year. In group two, at constant organic carbon, σ *decreases* with clay content but in a less well defined manner. At clay contents less than 16%, the minimum in this group of soils, it seems unlikely that stability will increase still further, but will decline instead to

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indicate that for a given amount of organic matter there is an optimum clay content for greatest stability.

When peroxide is used as an alternative dispersing agent then, depending on the soil, the amount of dispersion (particles <2 μm) may be more or less than that obtained by σ Jg^{-1} of ultrasonic energy. This suggests that the organic matter may be both more accessible and more amenable to chemical attack in some soils than in others. It is now thought that ultrasonic dispersion occurs in two stages. In the first, corresponding to the sharp increase in dispersion with energy, the loose natural clay–organic matrix is broken into micro-aggregate complexes. In the second, the near constant plateau thought originally to indicate weak disintegration of the basic clay material, these more tightly bound micro-aggregate complexes are disrupted. It is these complexes that are thought to provide the extra resistance to peroxide attack. Such secondary disaggregation would be expected to increase the relative amount of very small particles in suspension and has been shown to do so. Thus the specific stability index σ would seem to characterise only partial stability, but this need not detract from its usefulness as a structural parameter. The disruptive forces operating in the field are seldom likely to exceed those causing primary breakdown and the specific stability index, σ, is a measure of these. (North)

The tillage experiment. The mobile shelter and concrete track facilities in Little Knott I were used this year for the first time in a tillage experiment. These facilities were described last year in greater detail (*Rothamsted Report for 1974*, Part 1, 202) but essentially they protect the experimental area, if required, from rain, and support the wheels and weight of the tractor on concrete tracks allowing only the tillage implements to touch the soil. The objectives of the experiment were to examine whether tillage treatments caused measurable changes in the physical properties of the soil and whether these changes could, in turn, be related to crop growth and yield. As a preliminary, aimed at making the site as uniform as possible, several passes were made in October 1974 to a depth of 35 cm with a tine cultivator and the slight ridging left by this treatment was finally levelled with a power harrow operated to a depth of 8 cm. The whole area then remained covered until the spring cultivations were complete. Three cultivation treatments were applied to 18 plots in late April 1975; no cultivation with additional consolidation by Cambridge roller after seeding (T_0), no cultivation (T_1), and tine cultivation to a depth of 20 cm (T_2). Each treatment was carried out at three soil water contents; dry (W_0), wet (W_1) and very wet (W_2), corresponding respectively to 50, 83 and 100% of field capacity. Half the plots were sown with spring barley but all were worked with the spring-tined coulter seed-drill. A trickle irrigation system was used to wet the soil before cultivation, to bring all plots back to field capacity after seeding, and subsequently to ensure that the soil water deficit did not exceed 38 mm. Measurements of soil physical properties started five weeks before the spring cultivations and included twice weekly measurements of soil water content to a depth of 50 cm on all plots using a neutron probe, daily measurements of water potential to a depth of 25 cm on selected plots using tensiometers, and frequent measurements of gravimetric water content and bulk density. Carbon dioxide concentrations at depths between 5 and 30 cm were also measured on some plots (see below under Soil Respiration). Plant emergence, the number of tillers, the number of ears, and final yields of straw and grain were measured on all cropped plots. So far there is no consistent explanation of the variation in yields either in terms of the main tillage treatment, the soil water content at tillage, or their interactions. Superficially, the grain yields in Table 1 support the view that there is an optimum moisture content at which soil should be cultivated (in this experiment W_1) and that a soil can be left too loose (T_2) or too compact (T_0), but this is a gross oversimplification and there is a need to look in further detail at the various physical factors measured and their interactions. The maximum yield of grain

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TABLE 1

Effect of cultivations performed at three soil water contents on the yield of spring barley (Julia) 1975

	Yields at 85% dry matter (t ha^{-1})					
	Grain			Straw		
Soil water content as a fraction of field capacity	0·5 (W_0)	0·83 (W_1)	1·0 (W_2)	0·5 (W_0)	0·83 (W_1)	1·0 (W_2)
Cultivation treatment						
None + rolled (T_0)	4·98	5·62	5·92	7·15	7·45	8·38
None (T_1)	4·61	6·81	6·30	7·47	7·10	5·76
Tined to 20 cm depth (T_2)	5·92	5·58	4·57	7·57	7·89	4·10

(though not of straw) occurred on a minimum cultivation treatment (Table 1), but it is surprising to note that treatment T_1W_1 gave a substantially greater yield than either T_1W_0 or T_1W_2. The only differences in these three plots was in the water content of the soil at the time the seed drill passed. If the seed drill alone can have such an effect on the subsequent crop, then there is a risk that the effects of the drill have become similarly confounded with those of the roller (T_0) and those of the tines (T_2) making interpretation of the primary treatments more difficult. The worst yield followed a predictably bad treatment (T_2W_2) but not necessarily for the reason predicted; cultivations produced a tilth with very large clods and seedling emergence was 60% of that on other treatments, probably because the seed fell too deeply into the fissures between the clods. It is perhaps unfortunate that deprivations to the soil on the site during construction work in the winter 1973/74 made it desirable to give the additional preliminary cultivations in October 1974, and that in keeping the soil dry over winter so as not to prejudice the proposed watering regimes, the soil was denied the opportunity to consolidate in the winter weather before the final and all-important cultivations in spring 1975.

A point of general interest was noticed in June. The crop on the discard areas and on the surrounding field was noticeably poorer than on the plots. Subsequent analysis revealed a deficiency in nitrate in both soil and crop on those areas where the shelter had not protected the soil from the winter rain and consequent leaching. (Brown, A. T. Day, W. Day and Bolton)

Soil respiration. Respiration by plant roots and soil microorganisms depends on the interchange of carbon dioxide expired in the soil with atmospheric oxygen, a process effected largely by gas diffusion. Because diffusion is closely related to soil porosity, unsatisfactory crop performance, when associated with compacted soil, has often been attributed to poor soil aeration but seldom correlated with measured aeration status. Carbon dioxide concentrations at depths from 5 to 30 cm were measured daily from May until August on a combination of fallow, cropped, rolled and tilled plots in the tillage experiment. Probes of narrow-bore brass tubing, sealed at the upper end with rubber septa, were inserted into the soil and left *in situ* throughout the season. Gas samples (1 ml) were taken with hypodermic syringes and the carbon dioxide concentrations were measured with a gas chromatograph equipped with a thermal conductivity detector. In the fallow plots, carbon dioxide concentrations were governed mainly by temperature, and approximately doubled as the temperature increased from 10 to 20°C Irrigation and variations in soil water content had very little effect. Concentrations increased with depth and the highest measured in any fallow plot was 0·6% at 30 cm (normal atmospheric concentration is 0·03%). At 10 cm the concentration in the rolled plot (T_0) was almost three times greater than in the tilled plot (T_2). Under barley, the temperature relationship was overshadowed by the response to variations in soil water.

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For two or three days after irrigation the carbon dioxide concentration increased greatly but subsequently declined when water was withheld. The response was much less obvious at the beginning and end of the season when little root respiration was expected, and was absent from fallow plots. These results suggest that under barley the increase in carbon dioxide associated with watering is caused by a stimulus to respiration of the roots, or the microflora immediately associated with the roots, rather than by a decrease in air-filled pore space and hence diffusion. This must be of importance in the irrigation of crops. (Pritchard)

Water movement in soils. In tropical regions where crops such as upland rice, sorghum and maize rely on the monsoon rains, a false start to the monsoon can cause seeds to germinate then die for lack of sufficient water for further growth. In this problem infiltration, redistribution and evaporation of a small amount of water applied to a dry soil are important and were studied in detail. Three soils (a sand, a loam and a clay) were packed at uniform initial water potentials (pF 6, air dry; and pF 4·2, equivalent to being dried by plant roots) into replicate columns 30 cm deep and 1·25, 2·5 and 5·0 cm water were then applied as a single irrigation. These columns were maintained at 30°C in an atmosphere of 35–45% relative humidity for up to 30 days during which water profiles were measured at intervals by destructive sampling. Infiltration was rapid and the subsequent redistribution of water was almost complete in 2 h. The wetting fronts penetrated to depths ranging between 3 cm (1·25 cm water applied to air-dry clay) and 25 cm (5·0 cm water applied to air-dry sand) and thereafter water did not move downwards except as vapour in the air-dry soils. Evaporation caused the water profile to approximate to three zones; a dry zone between the soil surface and the drying front, a dry zone below the wetting front, and an intermediate wetter zone between drying and wetting fronts. As evaporation continued, the drying front moved deeper into the soil and the water content in the intermediate zone decreased. Evaporation was greater from the soils initially at pF 4·2, but for each soil a logarithmic plot of evaporation (E) *v.* time (t) gave straight lines for times exceeding one day, i.e. $E \propto t^n$ where n is 0·24 for the sand, 0·33 for the loam, and variable for the clay. If seeds are not to germinate prematurely they must be placed, either close to the soil surface so that the drying front passes them before imbibition is complete, or below the wetting front. If placed in the intermediate zone the probability of germination and of ultimate survival depends on the length of time for which soil water potentials remain favourable, and this in turn depends on the soil type and the amount of rainfall. (Rose, in collaboration with IITA, Ibadan)

Water relations and soil structure. The water content–suction relation (pF curve) has been examined in various problems concerned with aspects of soil structure and soil variability. Suction- and pressure-plates were used in the range pF 1·4 to 4·2 and equilibrium vapour pressure techniques from pF 4·5 to 7·0. All samples were disturbed and most were aggregates chosen to represent those units of soil structure and soil tilth that are hopefully stable in properties during soil management. The water content, θ, has been expressed as the volume of water per gram of soil. In soils receiving farmyard manure θ was greater over the whole range of pF, the increase being especially marked near pF 4, ranging from 20% in Barnfield and Saxmundham to 50% in Hoosfield and Broadbalk. Aggregate size had little effect on the pF curves except where in smaller aggregates the presence of free sand grains, or in large aggregates the presence of stones, changed the nature of the soil and decreased θ at a given pF. Where five soils were ignited, θ decreased at a given pF as ignition temperature increased to 700°C and then increased again in three of the soils at 850°C. Variations between soils from five sites within Meathop Wood, a National Nature Reserve in Cumbria, were large, but changes in soil type down the

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profiles were even larger so that a mean pF curve for each horizon could be obtained, and used, without ambiguity. (Rose and A. Day)

Irrigation. In the first five months of the year rainfall exceeded average by one-third and the soil remained at field capacity until the last week in May. By contrast, June, July and August, the most important months for crop growth, were the driest since 1921 with one-third of the normal rainfall, and the potential soil water deficit rose by the end of August to 280 mm. In the period 4 May to 21 September potential transpiration was 425 mm. In a year when irrigation should have benefited crops, barley, spring beans, spring wheat and potatoes in Greatfield received respectively 130, 180, 160 and 210 mm water. Irrigation started in mid-June for all four crops and ended in September for potatoes. The tendency for barley yields (Table 2) to be depressed by irrigation has been

TABLE 2

Effect of irrigation on the yields of spring barley (Julia), 1975

	Yields at 85% dry matter (t ha⁻¹)			
	Grain		Straw	
	No irrigation	Full irrigation	No irrigation	Full irrigation
'Nitro-Chalk'				
35 kg ha^{-1}	3·48	3·14	2·22	1·55
70 kg ha^{-1}	4·52	3·38	2·22	2·14
'Gold N'				
35 kg ha^{-1}	4·26	3·16	1·99	1·98
70 kg ha^{-1}	3·41	3·57	2·34	2·36

observed in previous years. This could have been caused by leaching or local water-logging and denitrification. When a soil is irrigated to field capacity there is little need for the roots to grow deep in search of water. In these circumstances nitrogen may well be leached beyond the reach of most active roots. Alternatively, at field capacity the structural units, the peds, clods and crumbs, may become anaerobic internally leading to denitrification, a risk that is increased in warmer soil in summer (see also under Soil Respiration). Irrigation proved more effective on beans when applied late (mid-July to mid-August) than early (mid-June to early July) (Table 3). Where aldicarb had been applied bean yields were depressed by early irrigation, probably because some of the

TABLE 3

Effect of irrigation on yields of spring beans (Minden, virus free), 1975

		Yield of grain at 85% dry matter (t ha^{-1})			
		Irrigation			
Row spacing (cm)	aldicarb (kg a.i. ha^{-1})	None	Early	Late	Full
18	0	1·57	1·72	1·94	2·40
	10	3·05	2·33	3·70	2·73
53	0	1·38	1·92	2·13	2·15
	10	2·69	2·52	3·26	2·55

pesticide was leached too deeply into the soil; the late irrigation by contrast, produced the largest yield in the experiment more than double that of the untreated, unwatered crop. (French and Legg)

The roots and soil on the plots receiving early and no irrigation were examined for

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Sitona weevil larvae. A moderate infestation (Table 4) was almost completely controlled by aldicarb (with Bardner and Fletcher, Entomology Department). Irrigation of potatoes (Pentland Crown) increased yields from 20 to 60 t ha^{-1}. (French and Whitehead)

TABLE 4

Effect of aldicarb in controlling Sitona *weevil larvae*

	Larvae per plant	Yield (t ha^{-1})
No irrigation, no aldicarb	8·71	1·38
No irrigation, with aldicarb	0·01	2·69
Early irrigation, no aldicarb	10·16	1·92
Early irrigation, with aldicarb	0·14	2·52

Yields of spring wheat on the micrometeorological macroplots were increased from 3·83 to 4·32 t ha^{-1} by irrigation. For most of the season the irrigated crop had 20–25% more cover and was 5–10% taller even though differences in germination and tillering were small. On both plots plant growth rate, measured with auximeters, was steady throughout the season ceasing abruptly on the unirrigated plots on 10 July and on the irrigated plot on 20 July. Large differences in microclimate were observed between the plots especially in profiles of temperature, moisture content and heat flux within the soil, and in the temperature and humidity profiles, leaf temperatures, and amounts and persistence of dew within the canopy. All available micrometeorological sensors were deployed in these two plots and as usual the results have been collected on punched tape. (Long and French)

Analysis of micrometeorological records. The success of much of the micrometeorological work depends on our ability to analyse and characterise a measured parameter so that it can be used to derive others not easily obtained directly. Thus the results of an analysis of wind profiles can be used in the calculation of evaporation and CO_2 flux. Wind profiles over the potato crop (1973) have been analysed in detail and by fitting a log-linear equation, values of d/h (d is the zero plane displacement, h the crop height), have been calculated. Such an equation was considered to be valid only when the effects of temperature gradient were small (i.e. for a Monin Obukhov length greater than 25 m) and for such hours d/h was found to decrease with increasing wind speed. It was also found that the same relationship could be used at all stages of crop growth. Perhaps surprisingly, as the potatoes were grown on ridges, no dependence of d/h on wind direction was observed even in the early season when the canopy was incomplete. (Legg and Woolhead)

Turbulent transport in the crop canopy: the Nitrous Oxide experiment. This experiment was done in 1969 and reported in some detail in 1972 (Legg, Ph.D. Thesis). Since then there has been opportunity to reconsider and to re-analyse the results and these have been re-presented in a more satisfactory and satisfying form (5, 6). Briefly air flow through the crop is always turbulent and it is necessary to be able to describe the vertical transfer of heat, momentum, water vapour, carbon dioxide and other gases in terms of a coefficient of turbulent diffusion K. Both the popular methods for measuring this coefficient have disadvantages: the energy balance method, from the diffusion of heat and water vapour. gives a coefficient, K_E, that is accurate only when net radiation is large, and the momentum balance method, giving K_M from the absorption of momentum by the crop foliage at different heights, requires a too detailed knowledge of leaf angle distribution and of the drag coefficients of the leaves at various orientations at different wind speeds. The nitrous oxide method aimed to measure K accurately at all heights and in all weathers

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in a wheat crop. Nitrous oxide was released from a network of nylon pipes at ground level to provide a uniform flux over a hexagonal plot 72 m wide. The nitrous oxide contents of air at several heights above ground at the centre of this area was analysed continuously using an infra-red gas analyser, and the diffusion coefficient K_N was calculated from the measured gradient and known flux. When the crop was short K_N above the crop agreed well with K_E and a K_M based on wind profiles. As the crop increased in height it was found that uniform flux could be obtained from a smaller area of distribution, and at a crop height of 1·25 m an area 24 m wide gave a vertical flux that was constant within 15% to a height of 1·0 m. The possible error in measuring K_N was estimated at from 10 to 15% below half crop height, increasing to 30–40% above 1·0 m. Comparison of K_N with K_E at heights of 0·6, 0·8 and 1·0 m showed much scatter but a linear regression of K_E against K_N had a slope of $1{\cdot}17 \pm 0{\cdot}10$ with a non-significant intercept.

The mean daytime profile of K_N showed an exponential decrease within the crop, $K(z) = K(h) \exp(-\gamma(1 - z/h))$ with $\gamma = 4$ when $u(h)$ (the windspeed at crop height h) $< 1{\cdot}2 \text{ m s}^{-1}$ and $\gamma = 5$ when $u(h) > 1{\cdot}2 \text{ m s}^{-1}$. On clear nights the profile of K_N was frequently S-shaped with values less than $0{\cdot}001 \text{ m}^2 \text{ s}^{-1}$ at crop height but more than $0{\cdot}01 \text{ m}^2 \text{ s}^{-1}$ at about $\frac{1}{3}$ h. This shape was caused by unstable air (temperature gradient $\Delta T/\Delta z$ negative) within the crop but stable air (gradient positive) above. Although S-shaped profiles were never observed during the day, there was evidence that K_N was influenced more by temperature gradient than by wind speed, and it was found possible to relate $K_N(z)/u(h)$ to the non-dimensional stability parameter $\frac{g}{T} \cdot \frac{\Delta T/\Delta z}{(u(h)/h)^2}$.

For $0{\cdot}3 < h < 0{\cdot}8$ m then

$$u(h)/K_N = 193 \left(1 - 0{\cdot}9 \frac{g \, \Delta T/\Delta z}{T(u(h)/h)^2}\right)^{-2\cdot 9} \text{ m}^{-1}.$$

In these experiments K_N, K_E and K_M were necessarily measured in different parts of the same crop and the scatter between results is attributed to non-uniformity in the crop. Indeed, measurements of the horizontal variation in both N_2O and CO_2 concentration within the crop supported this. The observed wind profile was frequently S-shaped and this cast doubts as to the accuracy that can be obtained in analyses based on a simple one-dimensional diffusion coefficient such as K. It is possible that some momentum is transferred directly to the bottom of the crop by occasional large eddies rather than being passed down as the theory would require in a succession of small ones. If so, then the vertical movement of any commodity cannot be specified by the product of a diffusion coefficient K and a concentration gradient at one height, but must also depend on the shape of the concentration profile at other heights and on the vertical distribution of sources and sinks within the profile. (Legg and Long)

Water balance on small plots

Evaporation. Evaporation may be estimated from the micrometeorological parameters above a crop only when the fetch is adequate. On small plots, however, detailed measurements on the crop (e.g. leaf temperature, stomatal resistance) can be combined with simple meteorological measurements (e.g. humidity) to give an estimate of transpiration rate. Comparisons between these two methods have been attempted this year to test whether the 'small plot' method would be satisfactory for the Mobile Shelter water-stress experiment in 1976. Leaf temperatures may be measured rapidly with a suitable infra-red thermometer. Tests with one instrument (Wahl Heat Spy) have indicated that it is inadequately compensated for rapid changes in ambient temperature caused by air currents, and it has been possible therefore to make only spot measurements. (W. Day)

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In a small plot evaporation may vary across the width of the plot because of advection. Calculations have shown that on crossing from a dry into a wet plot there is a large step increase in water loss by plants at the boundary followed by a more gradual decrease across the plot to within about 15% of the anticipated equilibrium value. Variation across the plot is therefore small and it should still be possible to calculate water loss, as described above, applying the Monteith equation for evaporation to individual elements. (Legg and Woolhead)

Lateral movement of water. Where adjacent small plots receive irrigation at different rates, there could be significant boundary effects as water moves laterally at depth from the wetter to the drier soil. This movement has been examined in a simulation model. Water may also be transferred laterally by plant roots poaching on adjacent plots. These combined boundary effects are being tested by applying tritiated water to one plot and measuring its uptake by adjacent plants. (W. Day)

Assimilation of carbon dioxide and transpiration

Field measurements in the canopy enclosure. Measurements of gaseous exchange between the plants and the atmosphere were continued in the canopy enclosure. An improvement in the cooling within this transparent enclosure has meant that observations have been possible at lower temperatures in high light intensities (i.e. on hot sunny days). Carbon dioxide uptake by wheat increased as expected with leaf area reaching a maximum of 5·5 g m^{-2} h^{-1} at the start of flowering (Feekes scale 10.5.1) then falling again to 1·21 g m^{-2} h^{-1} at ripening. More detailed measurements during the period of maximum uptake showed, as in potatoes during 1974, that uptake increased steadily with air temperature to a maximum at 24°C then declined sharply. This decline corresponded to an increase in canopy resistance between 24 and 31°C. Transpiration, however, remained almost constant at 122 mg m^{-2} s^{-1} and as this value is of similar magnitude to transpiration in the field, this is taken as evidence that the canopy is imposing no additional stress on the crop, and that the crop in the field is behaving in a similar manner. The decline in uptake of carbon dioxide above 24°C is almost certainly due to stomatal closure possibly as the plant endeavours to maintain a constant rate of transpiration in spite of increased saturation vapour pressure within the leaf. These effects occur in unstressed plants. By contrast the decreased uptake observed in the afternoons can be ascribed to greater water stress within the plant leading to stomatal closure. Calculations from these results have shown that the canopy resistance to carbon dioxide transfer is of the same order as that of a single leaf. By comparison the canopy resistance to water vapour is much less. These observations would suggest that photosynthesis is confined to little more than a single leaf layer whereas transpiration occurs from several. (Leach)

The effects of water stress. The responses of photosynthesis and growth to water stress were measured both in the laboratory and the field. Measurements in the laboratory were made in the plant growth chambers at a range of carbon dioxide concentrations and light intensities on beans (*Vicia faba*) that had been either watered adequately or left without water for increasing periods. Stomatal resistance increased with leaf water stress causing a decrease in photosynthesis, but mesophyll resistance remained unchanged until plants were badly wilted (−20 bar leaf water potential). Except at these extreme potentials these effects were reversed on watering. By contrast the efficiency of the light conversion reaction (i.e. the change in photosynthesis with light intensity, dP/dI) was permanently decreased by severe stress suggesting an irreversible change in the system. Stomatal resistances and leaf water potentials were measured at different light intensities on pota-

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toes grown in the field. In general, increasing light intensity opened stomata; increasing stress caused closure. Light intensity predominated until stress reached 8–10 bar when wilting occurred and stomata closed even in bright light. These results and conclusions are reported in greater detail (1). (Whitehead)

Stomatal resistance measurements using porometers. A new continuous-flow porometer has been built and used. This differs from a design previously used in the department (Parkinson & Legg, *Journal of Applied Ecology* (1972) **9**, 669–675) in that the nitrous oxide cylinder has been replaced by an air pump, flow regulator, and drying tube, and a new humidity sensor substituted. These modifications mean that the instrument is lighter, uses air for preference, and as the sensor gives a voltage output proportional to relative humidity gives a direct reading of stomatal resistance. There is evidence of quite large discrepancies between results obtained with different types of porometer. Comparisons were made with two other instruments both measuring the time taken for the humidity inside a closed cup fixed to the leaf to increase over a fixed range (Van Bavel *et al.*, *Plant Physiology, Lancaster* (1965) **40**, 535–540). At Long Ashton Research Station, the Delta T porometer gave resistances for tea, lemon, and apple leaves about twice those indicated by our new porometer (W. Day and Legg, with Dr. M. R. Thorpe and Mr. B. Warrit (LARS)), whereas the Botany department porometer (Lamba Instruments) gave resistances similar for potatoes, about 25% greater for French beans and tobacco, variable from leaf to leaf on sugar beet, but up to 2·5 times larger for wheat (with G. Milford, Botany Department).

These disparities are disturbing and must be explained. At present stomatal resistances reported in the literature cannot be adequately compared, and those obtained in experimental work cannot be used as absolute values with the confidence required for subsequent calculations. (W. Day)

Stomatal changes in response to light. The speed at which stomatal apertures change in response to fluctuations in light intensity must influence both transpiration and photosynthesis in the field. Preliminary experiments with field beans in leaf chambers have indicated an exponential decrease in stomatal conductance (time constant about 7 min), for a step-wise decrease in light. The response to increase in light is less well defined and has a longer time constant. (W. Day and Parkinson)

A leaf chamber, small enough to fit on to a microscope stage, and incorporating both a mixing fan and temperature control has been constructed. By using a long-focus high-power microscope objective it is possible to view a single stoma and photograph alterations in aperture with changes in light intensity and carbon dioxide concentration. Stomatal resistances are calculated from the dimensions on the photographs, using the equations of Milthorpe and Penman (*Journal of Experimental Botany* (1967) **18**, 422–457), and are compared with those from measured fluxes of water vapour. (Parkinson and Dominy)

Light interception by young crops. An important part of crop growth occurs before individual plants coalesce and this stage cannot be modelled using existing programs for light penetration into an entire canopy. In a model developed for this critical period of growth individual plants are represented by cylinders with axes vertical and an array of equal cylinders at field spacings is generated to represent the crop. Rotating in 1° steps about the axis (stem) of a test plant, the horizon presented by surrounding plants is scanned and the angle of elevation of the top of the nearest cylinder seen in each direction from each of five heights on the stem is calculated. These angles are a measure of the likelihood of shading from light coming from each direction. As an example of the use of

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this model, the effect of row directions on interception of direct light by a crop was examined, using another program to provide direction and angle of elevation of the sun for each hour in the day and typical plant measurements from the field. For kale (1972) with plant cover increasing from 4% in June to 34% in July and for field beans (1973) increasing from 2 to 15% in May the optimum row direction is east–west. For potatoes (1973), however, with ground cover increasing from 10 to 42% in June, the optimum direction for early growth was east–west but changed to north–south later, this effect being attributed to the short and spreading habit of the potato plant. (Parkinson)

Photorespiration. The fraction of CO_2 already fixed by the plant but subsequently lost in photorespiration decreases with decreasing temperature so it has been suggested that the C_3 temperate plants which do photorespire may not be so inefficient when growing at their normal temperatures. This idea has been tested in the plant growth chambers. As photorespiration is inhibited at low concentrations of oxygen, it can be effectively measured as the difference between net assimilation of carbon dioxide at oxygen concentrations of 5 and 21% but at equal temperatures and CO_2 concentrations. Beans (*Vicia faba*) were grown at 15 and 22·5°C and 450 μl CO_2 litre^{-1} and as there was no difference between the dry weight gain at these two oxygen concentrations, there is no difference in photorespiration at these temperatures and this CO_2 concentration. However, as 450 μl CO_2 litre^{-1} is somewhat above ambient, and as increased CO_2 also inhibits photorespiration, the experiment is to be repeated at 250 μl CO_2 litre^{-1}. (Parkinson)

Staff and visiting workers

No head of the department has yet been appointed. D. A. Rose left at the end of May to join the staff of the Glasshouse Crops Research Institute, Littlehampton. D. Whitehead, ARC Scholar, joined the Department of Forestry and Natural Resources, University of Edinburgh, on completing his Ph.D. Thesis. M. Derry was awarded the degree of B.Sc. at Hatfield Polytechnic. C. J. Bolton, P. Dominy, N. Glendenning and D. Woolhead all spent some time in the department as sandwich course students. T. N. Pedersen, Denmark, joined the department for three weeks as a vacation worker. Dr. M. J. Aston of the Australian National University spent six months of his sabbatic leave in the Physics and Botany departments.

Publications

Thesis

1 Whitehead, D. (1975) The effects of water stress on the photosynthesis and growth of plants. Ph.D. Thesis, University of London.

General Paper

2 Day, A. T. (1974) Weather 1973. *Transactions of the Hertfordshire Natural History Society* **27**, 291–292.

Research Papers

3 Evans, K., Parkinson, K. J. & Trudgill, D. L. (1975) Effect of potato cyst-nematodes on water relations and growth of a resistant and a susceptible variety of potato. *Nematologica* **21**, 273–280.

4 Gibson, R. W., Whitehead, D., Austin, D. J. & Simkins, J. (1976) Prevention of potato

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top-roll by aphicide and its effect on leaf area and photosynthesis. *Annals of Applied Biology*, **82**, 151–153.

5 LEGG, B. J. (1975) Turbulent diffusion within a wheat canopy: I. Measurement using nitrous oxide. *Quarterly Journal of the Royal Meteorological Society* **101**, 597–610.

6 LEGG, B. J. & LONG, I. F. (1975) Turbulent diffusion within a wheat canopy: II. Results and interpretation. *Quarterly Journal of the Royal Meteorological Society* **101**, 611–628.

7 LEGG, B. J. & (MONTEITH, J. L.) (1975) Heat and mass transfer within plant canopies. In: *Heat and mass transfer in the biosphere. I. Transfer processes in plant environment*. Ed. D. A. de Vries & N. H. Afgan. New York: John Wiley & Sons, pp. 167–186.

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