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## Report for 1959

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## Abstracts of Papers

### Rothamsted Research

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## ABSTRACTS OF PAPERS

### Physics Department

- 1.1. CURRIE, J. A. (1960). Gaseous diffusion in porous media. I. A non-steady state method. *British J. appl. Physics*, **11**.

Laboratory equipment, capable of modification for use on soils in the field, was built for studying diffusion in porous systems. A simple katharometer employs the exposed element of a thermal milliammeter to measure the instantaneous composition of hydrogen/air mixtures, the most convenient working condition being when 15 mW are dissipated in the hot wire, at which the thermocouple output changes from 0.5 mV in pure hydrogen to 2.5 mV in air. The geometry of the experimental system is simple enough to permit the application of a standard solution of the non-steady state equation for inter-diffusion of two gases; as a check on performance, straight tubes of slightly varying geometry were used to measure the diffusion coefficient of hydrogen into air, and its dependence on temperature. Reproducibility was very good, and within the limits of experimental error the coefficient obtained was the same for 100% H<sub>2</sub> into 100% air, and 60% air + 40% H<sub>2</sub> into 100% air. Measurements at 12°, 20°, 28° and 36° C., fitted  $D = D_0 (T/273)^n$ , with

$$D_0 = 0.651 \text{ cm.}^2 \text{ sec.}^{-1} \text{ at N.T.P.}$$
$$n = 1.715.$$

Standard values in the literature are  $D_0 = 0.611$  (I.C.T., 1929), 0.634 and 0.661 (Smithsonian Physical Tables 1954). The latter reference gives  $n = 1.75$ .

- 1.2. CURRIE, J. A. (1960). Gaseous diffusion in porous media. II. Dry granular materials. *British J. appl. Physics*, **11**.

The diffusion of hydrogen through cylindrical samples of porous granular materials, 3 inches long and 2 inches diameter, was measured by the non-steady state technique of Part I, and reduced coefficients of diffusion,  $D$ , referred to the value  $D_0$  in free air were calculated for over twenty materials with porosity  $\epsilon$  between 0.18 and 0.98. Results are comparable with those obtained by other methods, and with those for analogous electrical properties of porous media. Replicate determinations on a given sample agree to within 1%, but larger differences, caused by variations in packing, occur between duplicate samples of the same porosity. It is shown theoretically that  $D/D_0 = (l/l_0)^2 \cdot f \cdot \epsilon$ , where  $f$  and  $l/l_0$  are factors for non-uniformity of cross-section and the increased length of the tortuous path followed by the gas respectively. The influence on  $D/D_0$  of not only porosity but also particle shape was clearly shown, and so there can be no unique relationship for all materials, as often supposed, between diffusion rates and porosity. The equations of Burger and Bruggeman, both of which include a *particle* shape factor, were tested on the experimental data, and neither is entirely satisfactory. An empirical equation of the form  $D/D_0 = \gamma \epsilon^\mu$  fits all materials where  $\gamma (\leq 1)$  and  $\mu (\geq 1)$  are constants for a specific type of granular material, and probably represent measures of *pore* shape. Two particle-shape parameters, relative surface area and equivalent settling radius, were measured for a limited number of materials, but at best, only a general trend between these and the experimental values for the Bruggeman shape factor was observed.

- 1.3. EMERSON, W. W. & DETTMANN, MARGARET G. (1959). The effect of organic matter on crumb structure. *J. Soil Sci.* **10**, 227-234.

Tests on soil crumbs from nearby long-term arable and grassland fields showed that: (a) the rate of water uptake by dry crumbs at 98% relative humidity was the same for arable and grassland crumbs and also grassland crumbs pretreated with H<sub>2</sub>O<sub>2</sub>; (b) dry arable and grassland crumbs swell in water to the same amount. The crystalline swelling of the clay in soil crumbs seems unaffected by the soil being under grass. The general arrangement of

the quartz and orientated clay in thin sections of arable and the corresponding grassland crumbs was similar.

Slaking and dispersion tests on the natural crumbs, and on re-moulded crumbs formed by drying from a paste of the natural crumbs, suggested that remoulding does not disperse the clay in either the grassland or arable crumbs, but does break up many of the aggregates between 50 and  $2\ \mu$  diameter in the grassland crumbs. The natural arable crumbs were so weak that immersion wetting of the dry crumbs alone broke up the aggregates.

- 1.4. MONTEITH, J. L. (1959). Solarimeter for field use. *J. sci. Instrum.* **36**, 341–346.

A thermopile solarimeter was made from simple materials, with output  $5.5\ \text{mV cal.}^{-1}\text{cm.}^{-2}\text{min.}^{-1}$ ; resistance 13 ohms; response time 20 s; weight 35 g.; dimensions  $4 \times 4 \times 4\ \text{cm}$ . It can be used with a portable millivoltmeter to measure reflexion coefficients, radiation within crops, etc. General equations for solarimeter performance and a simplified theory for the present design give a non-linearity of  $-0.8\%$   $\text{cal.}^{-1}\text{cm.}^{-2}\text{min.}$  and a temperature coefficient of  $-0.12\%$  per degree C. Outdoor comparison with a Kipp solarimeter gave  $\pm 0.03\ \text{cal.cm.}^{-2}\text{min.}^{-1}$  as the maximum deviation from the mean response with radiation up to  $1.1\ \text{cal.cm.}^{-2}\text{min.}^{-1}$ . The standard deviation for thirty observations in bright sunshine and with overcast skies was  $\pm 0.002\ \text{cal.cm.}^{-2}\text{min.}^{-1}$ . Cosine and azimuth response were improved using a larger instrument of the same design, and comparisons of this with a Kipp solarimeter gave maximum deviation of  $\pm 0.02\ \text{cal.cm.}^{-2}\text{min.}^{-1}$ .

- 1.5. MONTEITH, J. L. (1959). The reflection of short-wave radiation by vegetation. *Quart. J. R. met. Soc.* **85**, 386–392.

The fraction of short-wave radiation reflected from agricultural crops was measured from May till September 1958 using two portable solarimetric thermopiles. Maximum reflexion coefficients for grass, lucerne, potatoes, sugar beet and spring wheat were between 0.24 and 0.27. Lower values in the early stages of crop development, and for spring wheat even at maturity, can be correlated with low leaf areas; and mutual shading of the leaves also decreased reflexion. Data by Billings & Morris (1951) were used to compute total reflexion coefficients for different types of vegetation, including two desert species, and to explain why these do not normally differ as much as the coefficients for the visible component.

- 1.6. MONTEITH, J. L. & SZEICZ, G. (1960). The performance of a Gunn–Bellani radiation integrator. *Quart. J. R. met. Soc.* **86**, 91–94.

An alcohol-filled Gunn–Bellani radiation integrator, exposed at Rothamsted from June till December, 1958, gave weekly distillation totals that were a linear function of short-wave radiation on a horizontal surface above a limit of  $500\ \text{cal./cm.}^2/\text{week}$ . Laboratory experiments with both alcohol- and water-filled models reveal a threshold radiation intensity which can be estimated from the properties of the distilling fluid and the partial pressure of air within the instruments. Distillation is negligible below the threshold, but above it is proportional to the excess radiation. Because the relation between absorbed heat and radiation incident on a horizontal surface depends on solar altitude and on the proportions of direct and diffuse radiation, it is difficult to predict field response from laboratory data.

- 1.7. MONTEITH, J. L. & SZEICZ, G. (1960). The carbon dioxide flux over a field of sugar beet. *Quart. J. R. met. Soc.* **86**, 205–214.

The difference in  $\text{CO}_2$  concentration at two heights above a sugar-beet crop was measured with a sensitive infra-red gas analyser. The ratio of evaporation to humidity gradient and of total heat flux to wet-bulb temperature gradient gave a transport number for calculating  $\text{CO}_2$  flux, assumed proportional to  $\text{CO}_2$  gradient and wind speed. In August and September 1958 there was often a constant upward flux at night (mean  $0.05\ \text{mg.cm.}^{-2}\text{hr.}^{-1}$ ) attributed to respiration by plants and soil micro-organisms; but during daylight, photosynthesis gave a downward flux varying with solar radiation and reaching a maximum of  $0.4\ \text{mg.cm.}^{-2}\text{hr.}^{-1}$ . From 31 July to 11 September

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the net downward flux of atmospheric CO<sub>2</sub> was 158 ± 29 mg./cm.<sup>2</sup> compared with an uptake of 217 ± 38 mg./cm.<sup>2</sup> estimated from dry matter increase of sampled plants. During October there was a net upward flux of 4.9 mg. cm.<sup>-2</sup>day<sup>-1</sup> attributed to a striking increase in amount of CO<sub>2</sub> produced in the soil.

- 1.8. PENMAN, H. L. & LONG, I. F. (1960). Weather in wheat—an essay in micrometeorology. *Quart. J. R. met. Soc.* **86**, 16–50.

Data for three summers (1955–57) are presented, obtained from continuous recorders responding to temperature, humidity and wind in and above the wheat crop at levels up to about 2 m. *Section 1* describes the instruments (see Long, *Quart. J. R. met. Soc.* **83**, 202, for details) and *Section 2* the site, 70 × 70 m., which may have been too small for full development of profiles. *Section 3* (from 1955) shows that planting density affects the daily cycles of temperature and humidity in the crop, a thin crop having a lower average relative humidity and a shorter period of saturation on a dew night. Such a night is characterised by a humidity lapse between ground and canopy, and a humidity inversion above the canopy. On the exceptional occasion illustrated both the up flux and the down flux may have reached a maximum rate of about 3 mg./cm.<sup>2</sup> ground/hour. An adventitious air temperature ripple during a calm night is exploited to derive rough estimates of transport constant in a dense crop: near the ground it approached the molecular thermal diffusivity for air. *Section 4* (from 1956) displays anomalies in temperature and humidity profiles that can arise from interpolating readings within the 400-second cycle of the recorders. It also gives soil temperatures, from which soil thermal diffusivity and soil heat flux are estimated, indicating that on the first sunny June day after rain net heat flux into the ground may be about 30 cal./cm.<sup>2</sup>—the equivalent of ½ mm. of evaporation. Further rough estimates of heat transport constant within the crop are of order 2–20 cm.<sup>2</sup>/sec., depending on height and external wind speed. The anomalies in profiles are attributed partly to periodicities in the air parameters almost identical with that of the recording instruments, and partly (*Section 5*, from 1957) to long-persisting differences in temperature and humidity at constant level across the site. Within the crop an average temperature difference of 0.8° C. may persist for four hours at positions 8 m. apart (and a vapour difference of 1.0 mb.), and these “hot” and “damp” spots—not always coincident—move slowly during the day. The differences are smaller above the crop where mixing is more thorough.

*Section 6*, introducing an analytical Part II which uses the data from a period of 8 days (12–19 June 1957) of fine weather after rain, discusses the generalised profile equation

$$u = \frac{u_*}{k\alpha} \left\{ \left( \frac{z-d}{z_0} \right)^\alpha - 1 \right\}$$

(reducing to the standard logarithmic profile when α = 0): measurements of temperature and humidity are not accurate enough to determine α for their profiles, and the swaying of the crop necessitates use of long-period averages of wind speed before α can be determined for wind profiles. Working on 4-hour periods (00–04, 04–08 and so on) (*Section 7*), profiles above the crop can be fitted either with α = 0, or a value of α chosen from the Deacon curve of 1 – α against Richardson number. Values for a crop height of about 60 cm., with heat transfer (Q<sub>s</sub>) and evaporation (E) rates from later sections, are:

Period		0–4	4–8	8–12	12–16	16–20	20–24
Ri		0.080	–0.007	–0.017	–0.010	0.014	0.046
Chosen α		0.20	–0.03	–0.05	–0.04	0.03	0.10
u <sub>*</sub> /k	cm./sec.	17	75	158	181	127	66
u <sub>*</sub> /k for α = 0	cm./sec.	59	67	132	158	130	92
z <sub>0</sub> for α = 0	cm.	5	5	11	14	12	12
d for α = 0	cm.	38	37	22	14	18	25
Q <sub>s</sub> (calc.)	cal./cm. <sup>2</sup> /4 hr.	–15	+4	+32	+14	–26	–33
E <sub>A</sub> (calc.)	cal./cm. <sup>2</sup> /4 hr.	–0.2	10	82	106	49	14
E <sub>B</sub> (measured)	cal./cm. <sup>2</sup> /4 hr.	–0.2	24	96	107	57	5

The discrepancy in u<sub>\*</sub>/k during the first period corresponds to a 12-fold difference in estimated shearing stress.

Wind profiles in the crop differ completely in shape during calm and windy weather, in the sense that near the ground the absolute wind speed tends to be constant: the crop behaves as though self-sealing.

Temperature and humidity profiles (*Section 8*) plotted in the form of wind speed against  $T$  or  $e$  at the same height are, statistically, straight lines above crop level, and in *Section 9* these straight lines are used to determine sensible heat and latent heat transfers (using  $\alpha = 0$ ) for the 48 4-hour periods in the 8 days. The daily totals, and the mean diurnal cycle of evaporation, agree well with direct measures taken simultaneously. Evaporation at night is negligible (see table above). The daily cycle of temperature and humidity (*Section 10*), considered in a little more detail during transitions to inversion or lapse, on a "normal" day and on a day of anticyclonic subsidence, indicates that very dry air does not increase evaporation rates—the local energy balance still dominates. The crop seems to meet the threat of severe desiccation by closing its stomata, and a speculative *Section 11* attempts to calculate rates of transfer from the leaves into the ambient air, at various levels in the crop, in terms of leaf morphology, leaf temperature and a ventilation factor. Applied to two periods, one calm with wet surface soil, the other windy with dry surface soil, about half of the water evaporated on the first occasion apparently came from the soil, and none on the second. The total fluxes so estimated agree well with aerodynamic estimates based on wind and humidity profiles over the crop. Derived estimates of transport constant well down in the crop show near identity in calm and in windy periods (cf. wind-velocity measurements, *Section 7*), and at the crop surface they agree well with aerodynamic estimates. *Section 12* discusses some biological and physical implications of the results.

### Chemistry Department

#### BOOKS

- 2.1. COOKE, G. W. (1960). *Fertilizers and profitable farming*. London: Crosby Lockwood.
- 2.2. COOKE, G. W. (1958). Contributor to: *Efficient use of fertilizers*. Ed. by V. Ignatieff and H. J. Page. Rome: Food and Agriculture Organisation of the United Nations.

#### REVIEWS AND GENERAL PAPERS

- 2.3. COOKE, G. W. (1959). Fertilizers, crop production and soil fertility. *J. Fmrs' Cl., Lond.* 1959 (5).
- 2.4. COOKE, G. W. (1959). Soils and fertilizers. *J. R. agric. Soc.* **120**, 126–144.
- 2.5. COOKE, G. W. (1959). Research on use of fertilizers: Britain's experiments. *Good farming quarterly*, **10** (3), 34–43.
- 2.6. MATTINGLY, G. E. G. (1958). Crops. *Rep. Progr. appl. Chem.* **43**, 578–585.

#### RESEARCH PAPERS

- 2.7. ARAMBARRI, P. & TALIBUDEEN, O. (1959). Factors influencing the isotopically exchangeable phosphate in soils. Part I. The effect of low concentrations of organic anions. *Plant & Soil*, **11**, 343–354.

The labile phosphate in a non-calcareous and a slightly calcareous soil was determined by isotopic exchange in the presence and absence of 0.001M solutions of a chelating and a non-chelating organic anion. The rate of isotopic exchange curves were analysed graphically to subdivide the labile phosphate into 3 or 4 fractions. The half-lives of exchange for the "rapid", "medium" and "slow" fractions were between 0.3 to 1.6 hours, 1.8 to 8.6

hours and 25.8 to 46.1 hours, respectively. An "instantaneously-exchanging" component was also sometimes observed.

In the presence of the citrate ion, the total labile phosphate was increased in the non-calcareous soil and decreased in the calcareous soil, whereas the diethyl barbiturate ion (DEB) anions decreased the total labile phosphate in both soils. In general, the citrate ion increased the "rapid" and the "medium" fractions, whereas the DEB anion either did not affect them or decreased them. Again, whereas citrate always increased the phosphate in solution, the effect of DEB anions depended on the soil. The major effect of the organic anions was to decrease the "slowly-exchanging" fraction in both soils.

The half-lives of exchange for the "rapid", "medium" and "slow" fractions were in the order

No organic anion > Citrate > Barbiturate

and the rate constants for a first-order mechanism were in the order

No organic anion < Barbiturate < Citrate

Small but significant differences were observed between the two soils.

- 2.8. ARAMBARRI, P. & TALIBUDEEN, O. (1959). Factors influencing the isotopically exchangeable phosphate in soils. Part II. The effect of base saturation with sodium and calcium in non-calcareous soils. *Plant & Soil*, **11**, 355-363.

The effect of base saturation of non-calcareous soils with sodium and calcium on their total labile phosphate was studied in solutions of sodium and calcium chlorides of the same ionic strength ( $\mu = 0.02$ ). The total labile phosphate in 6 out of 7 soils was between 8 to 40% higher in sodium-saturated soils than in calcium-saturated soils. Much more of the total labile phosphate was in solution in the sodium-saturated soils. The ratio of phosphate in solution in these soils to that in calcium-saturated soils varied from 3.4 to 8.1, with a mean value of about 5.5, as compared with a theoretical value of 4.1. A method is suggested for obtaining "corrected" values for the abnormally high phosphate concentrations in solution from sodium-saturated soils. "Corrected" values give smaller differences between the total labile phosphate in sodium and calcium forms of these soils.

Rates of isotopic exchange of the more slowly exchanging forms of soil phosphate were measured at 25° and 35° C for the sodium- and calcium-saturated forms of one Rothamsted soil. At 25° C rates were four times higher in the sodium-saturated soil than in the calcium-saturated soil, although the total labile phosphate in the two forms was the same. Increasing the temperature to 35° C doubled the rate of exchange in the sodium-saturated soil but had no effect on the calcium-saturated soil. This suggests that the cation-exchangeable calcium is strongly linked to the slowly-exchanging forms of phosphate in the soil.

The rates of isotopic exchange of phosphate in this soil did not change after calcium saturation with either 0.01M or 1.0M calcium chloride, so precipitation of calcium phosphates during the calcium-saturation procedure is not responsible for the differences between sodium- and calcium-saturated samples.

- 2.9. ARAMBARRI, P. & TALIBUDEEN, O. (1959). Factors influencing the isotopically exchangeable phosphate in soils. Part III. The effect of temperature in some calcareous soils. *Plant & Soil*, **11**, 364-376.

The influence of temperature in the range 25°-45° C. on the rate of dissolution and the equilibrium concentration of phosphate, on the labile phosphate and its components, and on the rates of isotopic exchange in four soils with varying CaCO<sub>3</sub> contents and phosphate status, was investigated. The equilibrium phosphate concentration and the rate of exchange of the slowly labile phosphate of soils of low P status increased abnormally between 35° and 45°. The slowly exchanging component normally constitutes the greater part of the labile phosphate of the soil. Soils of higher phosphate status, irrespective of their CaCO<sub>3</sub> content, did not show this abnormal behaviour. The observed difference is connected with the nature and the composition of the basic calcium phosphates associated with the soil calcium carbonate.

- 2.10. BENZIAN, B. (1959). Nutrition problems in forest nurseries. *J. Sci. Fd Agric.* **10**, 637-644.

Results from many experiments with Sitka spruce to analyse problems of soil fertility and plant nutrition in forest nurseries show that commercial fertilisers (such as "Nitro-Chalk", ammonium sulphate, superphosphate and potassium chloride) can safely be used in seedbeds and transplant beds.

Effects in short-term experiments with composts and uncomposted organic manures, with and without additional fertiliser, were related to the major plant nutrients present. Interim results for two long-term rotation experiments, which compare continuous conifer cropping with conifer cropping interrupted by fallow or green crops, showed no benefit from the green crops. Seedlings grown with fertiliser were slightly taller than those grown with compost on average of 8 seasons.

Needle tip-burn in a heathland nursery on a highly leached acid sandy soil was recognised to be caused by copper deficiency and was cured with a foliar application of Bordeaux mixture.

In some older nurseries, often with soil of neutral or near neutral reaction, Sitka spruce and some other conifers remain stunted even with ample manuring. Although the cause is not understood, good growth was obtained after soil acidification, after steaming and after applying formalin or chloropicrin.

This work, which was started in 1945, was done in co-operation with members of the Research Branch of the Forestry Commission.

- 2.11. BREMNER, J. M. (1959). Determination of fixed ammonium in soil. *J. agric. Sci.* **52**, 147-160.

A method of determining fixed ammonium in soil based on estimation of the difference in the amounts of ammonium released on treatment with *N*-HF : *N*-HCl and with *N*-KCl was investigated and compared with the hydrofluoric acid method of Rodrigues and the alkaline distillation method of Barshad.

Results obtained by the *N*-HF : *N*-HCl procedure with profile samples of various soils indicated that 3-8% (average 5.6%) of the nitrogen in the surface soils and 9-44% (average 21.5%) of the nitrogen in the subsoils examined was in the form of fixed ammonium. Rodrigues's method gave much higher values, and Barshad's method gave much lower values.

The proportion of soil nitrogen released by acid hydrolysis as total-N and  $\alpha$ -amino-N decreased with depth in the soil profiles, whereas the proportion liberated as ammonium by acid hydrolysis increased with depth. Much of the ammonium released by acid hydrolysis was derived from fixed ammonium in clay minerals.

The proportion of soil nitrogen dissolved by *N*-HF : *N*-HCl increased with depth in the profile, whereas the proportion dissolved by neutral and alkaline reagents used to extract soil organic matter decreased with depth. On average, 23.2% of the nitrogen in the surface soils and 47.4% of the nitrogen in the subsoils was dissolved by a single treatment with *N*-HF : *N*-HCl at room temperature for 24 hours.

- 2.12. BREMNER, J. M. & HARADA, T. (1959). Release of ammonium and organic matter from soil by hydrofluoric acid and effect of hydrofluoric acid treatment on extraction of soil organic matter by neutral and alkaline reagents. *J. agric. Sci.* **52**, 137-146.

Treating soil with hydrofluoric acid had little effect on the extraction of organic matter by alkaline or neutral reagents, but it released much ammonium and organic matter. More than 90% of the nitrogen in Rothamsted soils was dissolved by repeated treatments with dilute solutions of hydrofluoric acid and sodium hydroxide.

Treating clay minerals with *N*-HF : *N*-HCl solution at room temperature for 24 hours quantitatively released fixed ammonium from clay minerals; similar treatment of soil is unlikely to decompose organic nitrogen compounds to ammonium. This treatment may provide a method for determining fixed ammonium in soil. Results obtained by it indicated that 4-8% of the nitrogen in surface soils and 19-45% of the nitrogen in subsoils examined was in the form of fixed ammonium.

Some mineral soils contain a significant quantity of ammonium and organic

matter intimately associated with clay minerals; this is not dissolved by neutral and alkaline reagents used to extract soil organic matter but is released by hydrofluoric acid.

- 2.13. CHAKRAVARTI, S. (1959). Phosphate equilibria in acid soils and phosphated clays with special reference to the role of iron and aluminium. Thesis accepted for Ph.D. Degree of London University.
- 2.14. COOKE, G. W. & WIDDOWSON, F. V. (1959). Field experiments on phosphate fertilisers, a joint investigation. *J. agric. Sci.* **53**, 46-63.

About 90 field experiments were done over 3 years to test dicalcium phosphate, nitrophosphate, ammoniated fertiliser and Gafsa rock phosphate. All comparisons were made in terms of fertilisers supplying the same total amounts of phosphorus.

Dicalcium phosphate dihydrate was approximately equal to superphosphate for potatoes, grass, kale and barley. In one group of swede experiments, mostly in the North-East of England, dicalcium phosphate was inferior to superphosphate, but it was equal to superphosphate in swede experiments on acid soils in wetter areas.

A nitrophosphate made in England on pilot-plant scale was consistently inferior to superphosphate for barley, potatoes and swedes.

A lightly-ammoniated powdered superphosphate was tested in 1 year, and a more heavily ammoniated granulated NPK mixture based on triple superphosphate was tested in 2 years. The phosphorus in both ammoniated fertilisers behaved similarly and was equal to phosphorus in superphosphate for barley and potatoes; for swedes grown on acid soils the ammoniated products were only two-thirds as efficient as superphosphate.

Gafsa rock phosphate used on acid soils gave yields of swedes and kale similar to those given by two-thirds as much phosphorus applied as superphosphate. Rock phosphate had little effect on the yield of grass cut 3 months after the fertiliser was applied even on acid soils; superphosphate applied at the same time increased yields. A few grass experiments on acid soils were continued to measure residual effects, and Gafsa phosphate became as effective as superphosphate. Gafsa had little immediate or residual effect on grass grown on neutral soils. Gafsa phosphate ground to pass a 300-mesh sieve gave the same yields of swedes, kale and grass as coarser materials of which 50-80% passed the 100-mesh sieve. Generally there was no justification for grinding rock phosphate more finely than is customary, but a few experiments showed significant gains from fine grinding.

- 2.15. COOKE, G. W. & WARREN, R. G. (1959). Manuring experiments on flax. *Emp. J. exp. Agric.* **27**, 171-186.

In 50 experiments on flax done in 1940-45 to test the effects of manuring on yield and quality of the crop, yields of total produce and deseeded straw were measured precisely, but processing introduced irregularities, and yields for scutched flax were less accurate.

Nitrogen increased average yield of total crop by about 5% and yield of green-scutched flax by about 2%. Phosphate increased both total yield and yield of processed flax by less than 2%. Potash increased average yields of total crop by only 1.5% and of green-scutched flax by 4%. The effects of fertilisers on yield of processed flax depended on the method of processing: nitrogen increased the yield of retted-scutched flax by about 7%, and potash by about 2%; phosphate had only a small effect.

Agricultural salt lowered yields of total crop, of green-scutched flax and the average percentage of scutched flax recovered from the straw.

The average increase in yield from ammonium sulphate was about half as much after grass as after 3 or more years' arable crops. Soils with more than 0.3% total N gave one-third the response to fertiliser nitrogen of soils containing less nitrogen. Measurements of citric-acid-soluble phosphorus and acetic-acid-soluble potassium identified soils where phosphate and potash fertilisers gave profitable responses.

Manuring of flax is justified only when chemical analysis or experience shows that the soil is deficient in one or more of the major plant nutrients.



- 2.16. GASSER, J. K. R. (1959). Soil nitrogen. IV. Transformations and movement of fertiliser nitrogen in a light soil. *J. Sci. Fd Agric.* **10**, 192-197.

Concentrations of  $\text{NH}_4^+\text{-N}$  and  $\text{NO}_3^-\text{-N}$  in the surface (0-6 inches) layer of a light soil, with and without added nitrogen fertiliser, were measured from May to October 1957 on plots free from vegetation and cropped with ryegrass.

Nitrogen fertilisers applied to the soil increased the concentration of mineral nitrogen in the surface layer. On bare land the level of mineral nitrogen in the surface soil remained high until July, when it was decreased by heavy and prolonged rain.  $\text{NH}_4^+\text{-N}$  from ammonium sulphate or urea was converted to  $\text{NO}_3^-\text{-N}$  slowly; 20 weeks were required to nitrify all the added nitrogen.

When established, ryegrass removed nitrate very rapidly from the soil and brought the level of  $\text{NO}_3^-\text{-N}$  to <1 p.p.m. both on plots with and without fertiliser-N. On plots dressed with ammonium sulphate  $\text{NH}_4^+\text{-N}$  was lost under ryegrass, with no corresponding increase in  $\text{NO}_3^-\text{-N}$ . The first cut of grass in July contained three-quarters and the second only one-tenth of the nitrogen applied as fertiliser.

Soil samples taken in October from depths up to 3 feet showed that mineral nitrogen did not accumulate under ryegrass and that nitrate moved downward in uncropped soil.

- 2.17. (McDONNELL, P. M., STEVENSON, F. J.) & BREMNER, J. M. (1959). Release of fixed ammonium from soil by ball milling. *Nature, Lond.* **183**, 1414-1415.

- 2.18. PLESHKOV, B. P. (& FOWDEN, L.) (1959). Amino-acid composition of the proteins of barley leaves in relation to the mineral nutrition and age of plants. *Nature, Lond.* **183**, 1445-1446.

- 2.19. SHAW, K. (1959). Determination of organic carbon in soil and plant material. *J. Soil Sci.* **10**, 316-326.

A wet-oxidation technique for determining organic carbon in soil, plant material and aqueous plant extracts is described. The oxidation is done by heating the soil or plant sample with a mixture of potassium dichromate, sulphuric and phosphoric acids for 10-15 minutes, and the carbon dioxide liberated is determined gravimetrically after absorption in soda-lime. With slight modifications, the method was used for determining carbon in plant extracts, and it seems suitable for soil extracts. A method is described for removing carbonates without loss of organic carbon. Heating a wet soil at 105°C. causes considerable loss of organic carbon. Inert carbonaceous material, such as coal or charcoal, is oxidised by this wet-digestion method, which gives erroneously high results for the carbon content of soil organic matter.

The method is at least as accurate as the conventional dry-combustion technique and quicker, requiring only 1 hour. The apparatus is simple, and except for the needle valve can be readily constructed from normal laboratory glassware.

- 2.20. TAYLOR, A. W. (1958). Some equilibrium solution studies on Rothamsted soils. *Proc. Soil Sci. Soc. Amer.* **22**, 511-513.

Experiments to find the variation in composition of solutions brought into equilibrium with samples of four different soils at widely different electrolyte concentrations are described. The ratio law relationship between the potassium- and calcium-ion concentration ( $a_{\text{K}}/\sqrt{a_{\text{Ca}}} = \text{constant}$ ) is strictly obeyed only in soils of low potassium status. Variations in soils which received large dressings of potassium are attributed to an exchange reaction by which the amount of readily exchangeable potassium increases as the electrolyte concentration is raised.

- 2.21. WARREN, R. G. & BENZIAN, B. (1959). High levels of phosphorus and die-back in yellow lupins. *Nature, Lond.* **184**, 1588.

In a Forestry Commission Research Nursery on very acid heathland soil near Wareham, Dorset, yellow lupins (*Lupinus luteus*) grown with fertiliser

often show disease signs, the older leaves shrivelling and occasionally the whole plants dying. Phosphorus values in severely affected plants reached 2.2% of the dry matter, and pot experiments with the soil confirmed that the trouble was caused by excess of phosphorus.

- 2.22. WEBSTER, R. & GASSER, J. K. R. (1959). Soil nitrogen. V. Leaching of nitrate from soils in laboratory experiments. *J. Sci. Fd Agric.* **10**, 584-588.

The leaching of nitrate was studied by percolating water through columns of clay loam and sandy loam soils.

The light soil lost nitrate more quickly than the heavy soil. Both heavy and light soils lost nitrate faster initially from a coarse fraction (2-10 mm.) than from the unseparated soil. A fine fraction (<2 mm.) of the heavy soil initially lost nitrate most quickly, but ultimately most nitrate was leached from the unseparated soil. When water was added slowly at the top of columns of unseparated soils until the bottom became wet, nitrate moved downwards, but not uniformly; both soils had a minimum in the nitrate concentration near the bottom of the column. It is suggested that drainage water flows initially over the structural units, and only through the mass of soil when it is completely saturated, so that nitrate is first lost from the surface of the structural units and later from the soil mass as a whole.

- 2.23. WIDDOWSON, F. V. (1959). The effects of nitrogen upon three stiff-strawed winter wheat varieties. *J. agric. Sci.* **53**, 17-24.

Eleven winter wheat experiments done from 1955 to 1957, compared the effects of nitrogen on Heine 7, Hybrid 46 and Minister. In 1955 the experiments tested "Nitro-Chalk" top-dressings at 0.45, 0.90 and 1.35 cwt. N/acre. In addition, drilled dressings supplying 0.15 cwt. N/acre were supplemented with either 0.30 or 0.75 cwt. N/acre as a top-dressing. In the 1956 and 1957 experiments "Nitro-Chalk" top-dressings were applied at 0.60 and 1.20 cwt. N/acre. In addition, divided dressings were compared by supplementing 0.15 cwt. N/acre by combine-drill with 0.45 cwt. N as top-dressing.

Yield was significantly increased by the first increment of nitrogen in 23 of the 33 comparisons. Additional gains from the second increment of nitrogen occurred in only 7 of the comparisons. Responses to nitrogen varied considerably between seasons. Large and consistent responses were obtained at all centres in 1955, and dressings supplying 0.9 cwt. N/acre were well worthwhile. In 1956 responses were generally smaller, and more than 0.6 cwt. N/acre was justified at only 2 centres. Mean responses in 1957 were lower than those in 1955 and 1956, and 0.6 cwt. N/acre gave maximum yields at 3 of the 4 centres.

Dividing dressings of nitrogen between autumn and spring produced no significant differences. On average, yields were higher when the whole of the nitrogen was given in spring than when part was given in autumn by combine-drill.

Hybrid 46, the only variety able to take consistent advantage of the heaviest rates of manuring, each year produced the highest percentage increase in yield, and Minister the lowest. Hybrid 46 also contained the highest percentage of nitrogen in the grain at each level of manuring. Hybrid 46 converted more of the fertiliser nitrogen into grain or crude protein than either of the other varieties.

- 2.24. WIDDOWSON, F. V., PENNY, A., WILLIAMS, R. J. B. & COOKE, G. W. (1959). The value of calcium nitrate for spring-sown cereals. *J. agric. Sci.* **52**, 200-206.

Seven experiments on spring barley and five on spring wheat in 1955-57 compared ammonium sulphate and calcium nitrate applied to the seedbeds at 0.3 and 0.6 cwt. N/acre. The fertilisers were tested both when broadcast and when drilled with the seed.

Consistently higher yields of barley were produced by drilling than by broadcasting ammonium sulphate. Drilling calcium nitrate at 0.3 cwt. N/acre was superior to broadcasting for barley, but when applied with the seed at 0.6 cwt. N/acre it retarded germination and early growth and yields were

smaller than when it was broadcast. Broadcast dressings of both fertilisers gave higher yields of wheat than combine-drilled dressings.

Calcium nitrate and ammonium sulphate gave similar yields and nitrogen contents of both crops when the fertilisers were broadcast on the seedbed. The low rate of both fertilisers did not affect the percentage of nitrogen in barley grown in 1955 and 1956, whereas the higher rate caused small increases. In 1957 both rates of dressing considerably increased the percentage of nitrogen in grain.

For stiff-strawed varieties of spring barley and spring wheat 0.5–0.6 cwt. N/acre should be applied when sowing; this rate is unlikely to cause serious lodging in eastern England. Ammonium sulphate and calcium nitrate are equally suitable, except that combine-drilling of the nitrate may check germination and decrease yield in dry weather.

- 2.25. WIDDOWSON, F. V., PENNY, A., WILLIAMS, R. J. B. & COOKE, G. W. (1959). Comparisons between combine-drilling and broadcasting muriate of potash for spring barley. *J. agric. Sci.* **53**, 10–16.

Twelve experiments in Bedfordshire and Hertfordshire in 1955–57 compared combine-drilling and broadcasting muriate of potash for barley. Ordinary mineral soils were used, one with more than 25% of calcium carbonate.

On average of all the experiments in each year, 0.25 cwt.  $K_2O$ /acre drilled with the seed gave higher yields than 0.5 cwt.  $K_2O$ /acre broadcast and worked into the seedbed. The average extra yields of barley from combine-drilling, as compared with broadcasting, were 1.2 cwt./acre with 0.25 cwt.  $K_2O$ /acre and 2.0 cwt./acre of grain with 0.5 cwt. of  $K_2O$ . In 21 of the 24 comparisons drilling gave higher yields than broadcasting, and in 8 the effects were significant. Combine-drilling gave higher average yields of straw than broadcasting.

The low and high rates of combine-drilled muriate of potash increased yields on average by 13% and 16%, respectively. Only a small proportion of the applied potassium was taken up by the crops; apparent recoveries by grain plus straw averaged 11% of the light drilled dressing and 8% of the heavy dressing. The response was not closely related to values for dilute hydrochloric-acid-soluble potassium or exchangeable potassium in the soils.

## Pedology Department

### GENERAL PAPERS

- 3.1. STEPHEN, I. (1959). Recent advances in pedology—Pedogenic weathering. *Sci. Progr.* **47**, 306–313.
- 3.2. STEPHEN, I. (1959). Some aspects of soil mineralogy. *Rep. Rothamst. exp. Sta.* for 1958, 205–213.

### RESEARCH PAPERS

- 3.3. AVERY, B. W., STEPHEN, I., BROWN, G. & YAALON, D. H. (1959). The origin and development of brown earths on Clay-with-flints and Coombe deposits. *J. Soil Sci.* **10**, 177–195.

For abstract see 17.1 below.

- 3.4. BROWN, G. & STEPHEN, I. (1959). Expanding-lattice minerals from Shropshire. *Miner. Mag.* **32**, 251–253.

X-ray and optical data are given for two types of expanding-lattice minerals occurring in weathered rock and soil in Shropshire.

- 3.5. GALLAVAN, R. C. (1959). Bulb breaking correction for heats of wetting determinations. *Brit. J. appl. Phys.* **10**, 398.

Some factors affecting the heat generated when an evacuated glass bulb is broken in water at 25° C. were studied using a calorimeter of high sensitivity.

The importance of the gaseous content of the water in the calorimeter is illustrated by deliberate variation of the carbon dioxide content. By careful control of factors discussed, heats of breaking were measured that are reproducible to  $\pm 0.005J$  of the mean value.

- 3.6. GREENE-KELLY, R. (1959). Birefringence of Montmorillonite Complexes. *Nature, Lond.* **184**, 181.
- 3.7. (GROSSMAN, R. B.), STEPHEN, I., (FEHRENBACHER, J. B., BEAVERS, A. H. & PARKER, J. M.) (1959). Fragipan soils of Illinois: II. Mineralogy in reference to parent material uniformity of Hosmer silt loam. *Proc. Soil Sci. Soc. Amer.* **23**, 70-73.

The mineralogy of Hosmer silt loam, a bisequal soil with a fragipan, was studied to determine whether there is a lithological discontinuity between the parent material of the upper and lower sequum. Differences observed between the two sequa in respect to the mineralogy of the heavy and light silt-sized fractions may be accounted for by a progressive decrease in the weathering intensity with depth and are not suggestive of a lithological discontinuity in parent material. The clay mineralogy for the B-horizons of the two sequa was similar for the  $2.0-0.2\text{-}\mu$  and the  $<0.2\text{-}\mu$  fractions taken individually. For the total clay fraction, however, a higher percentage of montmorillonite was in the B<sub>1</sub><sup>2</sup>-horizon of the lower sequum; this may be explained by illuviation.

- 3.8. (GROSSMAN, R. B.), STEPHEN, I., (FEHRENBACHER, J. B. & BEAVERS, A. H.) (1959). Fragipan soils of Illinois: III. Micromorphological studies of Hosmer silt loam. *Proc. Soil. Sci. Soc. Amer.* **23**, 73-75.

Micromorphological studies indicate that the B<sub>2</sub>-horizon of the upper sequum is at present an apparently stable, non-illuvial horizon, whereas the B-horizons of the lower sequum are illuvial in character, and in the process of degradation to form the encroaching A<sub>1</sub><sup>2</sup>-horizon. An attempt is made to relate resistance to mechanical breakdown of the major horizons to their micromorphology.

- 3.9. LE RICHE, H. H. (1959). Molybdenum in the Lower Lias of England and Wales in relation to the incidence of Teart. *J. Soil Sci.* **10**, 133-136.

An explanation is offered for the fact that the toxic levels of molybdenum occurring in the Lower Lias soils of Somerset do not occur in soils of Glamorgan, apparently derived from the same zones of the Lower Lias. This is attributable to the parent rock being free from the abnormally high levels of molybdenum found in Somerset, which in turn probably results from the Glamorgan Lias having been laid down close to the contemporary coastline.

Soils high in molybdenum are to be expected in the Vale of Marshwood (Dorset), but the topography of this district is such that they probably occur in too small pockets to cause serious trouble.

- 3.10. LE RICHE, H. H. (1959). The distribution of certain trace elements in the Lower Lias of southern England. *Geochim. et cosmochim. Acta*, **16**, 101-122.

The apparent rarity of the conditions which give rise to the teart disease of cattle in central Somerset has led to a study of the distribution of molybdenum in the Lower Lias shales from which the teart soils are derived.

Analyses of many specimens of shale from two boreholes and from outcrops on the coasts of Dorset and Glamorgan showed considerable variation over the formation, but correlations were found between the concentrations of molybdenum, vanadium, copper and nickel. The amounts of these elements in the shales are related to the organic carbon content, and these together are related to the percentage of calcium carbonate, reaching a maximum with 20-50% CaCO<sub>3</sub>.

Detailed study of one shale specimen showed that, despite the correlation of these elements with organic carbon, they are not all associated with it. Some of the molybdenum is associated with the silicates and pyrite, whereas nearly all the vanadium is in the silicates. Copper and nickel appear to be mainly organically bound, although some of the nickel is in exchangeable form.

### Soil Microbiology Department

#### BOOKS

- 4.1. WALKER, N. (1960). *Soil biology*. An English translation of "Bodenbiologie, mit besonderer Berücksichtigung der Tierwelt", by W. Kühnelt, with revisions and supplementary material by the author. London: Faber & Faber.

#### GENERAL PAPERS

- 4.2. COOPER, R. (1959). Bacterial fertilizers in the Soviet Union. *Soils & Fert.* **22**, 327-333.

#### RESEARCH PAPERS

- 4.3. GIBSON, A. H. (1959). A study of the physiology and cytology of nodule formation on legumes. (*Doctoral Thesis.*)

Small amounts of combined nitrogen (2 p.p.m. or more of  $\text{NO}_3\text{-N}$ —equivalent to 20  $\mu\text{g}$ . N/plant in the medium), delayed nodulation of clover and lucerne in direct relation to the amount of nitrate taken up by the plant (up to about 160  $\mu\text{g}$ . N/seedling). Similar concentrations of  $\text{NO}_3\text{-N}$  were equally inhibitory, whereas  $\text{NH}_4\text{-N}$  and certain organic forms of nitrogen did not inhibit, although they were assimilated at about the same rate as  $\text{NO}_3\text{-N}$ . The inhibitory effect of low concentrations of nitrate and nitrite ions is specific and not related to the carbohydrate-nitrogen balance within the plant. Small amounts of combined nitrogen increased the total number of nodules formed.

"Preplanting" media stimulates initial nodulation, largely because the preplant removes small amounts of contaminating nitrate nitrogen in the water, but in N-free medium substances secreted by the preplant also sometimes affect nodule formation slightly.

- 4.4. NUTMAN, P. S. (1959). Some observations on root hair infection by nodule bacteria. *J. exp. Bot.* **10**, 250-263.

The infection by nodule bacteria of the root hairs of *Vicia hirsuta* and of 12 species of *Trifolium* is described. The proportion of root hairs deformed by bacterial secretions varies between host species and from point to point along the root, but is unaffected by bacterial strain. Infection is more frequent in regions of maximum curling. Infection threads differ in their place of origin in the hair (apical or lateral), their mode of development and detailed morphology; some of these differences are characteristic of host species. Infection threads often abort in the root hair; abortion was least with 2-week-old seedlings infected at about 12 sites. The proportion of lateral infections increases with seedling age.

Root-hair curling, infection thread initiation and growth are associated with the near presence of the host-cell nucleus. The observations support the hypothesis that the infection thread forms by invagination of the root-hair wall.

No infections were observed in the root hairs of nodulated plants of *Lotus hispidus*, *Lotus augustissimus* and *Anthyllis vulneraria*.

- 4.5. PARLE, J. N. (1959). The influence of the soil fauna on the soil microorganisms. (*Doctoral Thesis.*)

The microflora of the gut of *Allolobophora caliginosa*, *Allolobophora longa* and *Lambricus terrestris*, and of the casts of *A. longa* were studied. The numbers of actinomycetes and bacteria present in material ingested by worms increased greatly during its passage through the gut, which usually took 24

hours. No changes were noted in the numbers of yeasts or fungi. Cellulase and chitinase were produced by the earthworm and not by the intestinal flora. The numbers of yeasts and fungi increased rapidly when casts aged, but actinomycetes or bacterial numbers did not change consistently. The stability of soil aggregates increased logarithmically as casts aged, and this was correlated with the increase in the length of fungal hyphae. Casts contained more polysaccharide than the soil. Total and mineral nitrogen levels in fresh casts were high; inorganic nitrogen was mainly as  $\text{NH}_3\text{-N}$ , which nitrifying organisms rapidly converted to nitrate.

- 4.6. SKINNER, F. A. (1960). The isolation of anaerobic cellulose-decomposing bacteria from soil. *J. gen. Microbiol.* **22**, 539-554.

A strictly anaerobic mesophilic species of cellulose-decomposing bacteria was isolated from soil by a new technique. Liquid and solid media containing finely-divided cellulose were used, and flocculation of the cellulose particles in agar medium was prevented by incorporating a little sodium carboxymethyl-cellulose. Cellulolytic colonies in cellulose agar medium were of two types, punctiform and spreading. The isolate, derived from a punctiform colony, digested cellulose, forming formic, acetic and malic acids, carbon dioxide and hydrogen. Surface colonies on yeast peptone cellulose agar were differentiated into convex central zones and thin, irregular margins. In deep culture with the same agar medium, the isolate either grew as discrete lenticular colonies or spread rapidly throughout the medium. Neither form was stable enough to isolate from the other, but spreading growth was partly suppressed by growing the isolate in yeast peptone cellobiose agar containing lithium chloride. The isolate is probably a strain of *Clostridium cellobioparum* Hungate, but differs from it in producing little or no cellobiose but abundant glucose from cellulose in liquid culture.

## Botany Department

### GENERAL PAPERS

- 5.1. THURSTON, J. M. (1960). Dormancy in weed seeds. *In: The biology of weeds. A symposium of the British Ecological Society*, ed. J. L. Harper. Oxford: Blackwell Scientific Publications. (In the press.)
- 5.2. WELBANK, P. J. (1960). Toxin production from *Agropyron repens*. *In: The biology of weeds. A symposium of the British Ecological Society*, ed. J. L. Harper. Oxford: Blackwell Scientific Publications. (In the press.)

### RESEARCH PAPERS

- 5.3. HUMPHRIES, E. C. & THURSTON, J. M. (1959). Bulbil formation in *Sedum telephium*. *Nature, Lond.* **183**, 1343.

Formation of bulbils on a vegetative plant of *Sedum telephium*, in the axils of the upper leaves where flowering stems would normally arise, is described. Bulbil formation has not previously been reported in the genus *Sedum*.

- 5.4. HUMPHRIES, E. C. & WHEELER, A. W. (1960). The effects of kinetin, gibberellic acid and light on expansion and cell division in leaf disks of dwarf bean (*Phaseolus vulgaris*). *J. exp. Bot.*

The effects of kinetin (Kn), gibberellic acid (GA) and light on cell expansion and division in disks from 6-day-old etiolated primary leaves of dwarf bean are described. Cell number was determined by direct counting after disks were digested in a pectinase/EDTA mixture to separate the cells. Kn increased leaf expansion wholly by increasing cell size. GA also increased cell size; it increased cell division in the dark, but not in the light. Light also increased cell size and cell division; it eliminated the effect of GA on cell division, but enhanced its effect on cell expansion.

- 5.5. MACIEJEWSKA-POTAPCZYK, W. (1959). Influence of kinetin,  $\beta$ -indoleacetic acid and gibberellic acid on nuclease activity of bean (*Phaseolus vulgaris*) hypocotyls. *Nature, Lond.* **184**, 557.

The activities of ribonuclease (RNase) and deoxyribonuclease (DNase) in extracts of bean hypocotyls were increased by addition of kinetin (Kn) alone, and still more in presence of indoleacetic acid (IAA). IAA alone had no effect, but in presence of Kn it increased the activities of both enzymes. Kn was effective in much lower concentrations on RNase than on DNase. Optimum concentrations of Kn and IAA doubled the activity of RNase and trebled that of DNase. Gibberellic acid had no effect on the activity of either enzyme.

- 5.6. MACIEJEWSKA-POTAPCZYK, W. (1960). Phosphorus compounds, nuclease, and phosphatase activities in healthy and tumorous stem tissues of *Datura stramonium* L. *J. exp. Bot.*

The phosphorus compounds, nuclease and phosphatase activities in healthy and tumorous stem tissues of *Datura* were compared. The very high level of P in the tumours comes from increased amounts of acid-soluble phosphorus, lipid phosphorus, ribonucleic acid phosphorus and deoxyribonucleic acid phosphorus.

The activities of ribonuclease, deoxyribonuclease and glycerophosphatase were all considerably higher in the tumours than in stem tissue.

- 5.7. THORNE, G. N. (1959). Photosynthesis of lamina and sheath of barley leaves. *Ann. Bot. Lond., N.S.* **23**, 365-370.

Apparent photosynthesis, in mg. CO<sub>2</sub> absorbed per dm.<sup>2</sup>/hour, of the sheath and enclosed stem of a barley leaf was about 50% of that of the lamina of the same leaf, when the photosynthesising area was measured as one side of the lamina and the outer exposed surface of the sheath. Apparent photosynthesis of a particular lamina or sheath was about 70% of that of the one above on the same stem.

Respiration per dm.<sup>2</sup>, though not per g. dry weight, of sheath with enclosed stem was greater than of lamina in one experiment done with low-intensity illumination, so that true rates of photosynthesis of lamina and sheath were similar.

For growth-analysis studies the size of the photosynthetic system of cereals should be measured as one side of the leaf laminae plus the outer surface of the combined leaf sheaths. In the later stages of growth the surface area of exposed stem and peduncle should also be included.

- 5.8. THURSTON, J. M. (1959). A comparative study of the growth of wild oats (*Avena fatua* L. and *A. ludoviciana* Dur.) and of cultivated cereals with varied nitrogen supply. *Ann. appl. Biol.* **47**, 716-739.

Wild oats (*Avena fatua* and *A. ludoviciana*) grown in pots with different levels of nitrogen supply showed many similarities to spring barley, winter oats and winter wheat. Small differences that could affect competition between wild oats and cereals occurred mainly in the seedlings. Wild-oat seedlings were smaller than seedlings of cultivated cereals in total dry weight, total nitrogen content, leaf area and number of shoots, but had higher net assimilation rates and soon caught up and passed the cultivated cereals. The difference in net assimilation rate did not persist, and in the later stages of growth differences in dry-matter production depended mainly on differences in leaf area. Another important contrast between wild oats and cultivated cereals was that 98-100% of the wild-oat seeds but none of the crop seeds were dormant 2 months after harvest.

Ear emergence in wild oats spread over a longer period, the range of ear heights was greater, and the tallest ears were smaller than in the corresponding cultivated cereals. Assimilation in the ear appeared to account for less of the total dry matter of plants of wild and cultivated oats than of wheat. Wild oats produced more seeds per plant, but the 1,000-grain weight, and hence the total dry weight of seeds, was less than in cultivated cereals.

Increased nitrogen supply had similar effects on the wild oats and cultivated

cereals. Wild oats took up the same amount of nitrogen per plant as winter oats and winter wheat, but more than spring barley.

It is concluded that wild oats are most susceptible in the seedling stage to competition from the crop, and that nitrogenous fertiliser applied to an infested field is unlikely to alter the balance between the yields of crop and of wild oats.

- 5.9. WATSON, D. J. & WITTS, K. J. (1959). The net assimilation rates of wild and cultivated beets. *Ann. Bot. Lond., N.S.* **23**, 431–439.

The net assimilation rate (E) of Kleinwanzleben sugar beet was the same as that of three types of wild sea-beet (*Beta vulgaris* subsp. *maritima*) when the leaf area index (L) was near to 1. In a subsequent period, when mean L of sugar beet and of the leafiest wild beet type was 2.5, there was an inverse relation between E and L of the three wild types, and E of sugar beet was then much greater than that of the wild type with equal L, but was little different from that of the wild type with smallest L (about 1.5). It is concluded that the development of sugar beet from its wild ancestors by selection and breeding has not affected the intrinsic photosynthetic efficiency of the leaves, but has diminished the effect of mutual interference between leaves, so that E falls less rapidly as L increases, i.e., it has decreased the leaf-density dependence of E. This change may be related to the difference in form between sugar beet and wild beet plants.

- 5.10. WITTS, K. J. (1960). The germination of *Polygonum* species in the field and in the glass-house. *J. Ecol.* **48**, 215–217.

Three species of *Polygonum* germinated equally during 1957, but *P. aviculare* and *P. convolvulus* ceased germinating in May, whereas *P. persicaria* continued until July. The greater abundance of *P. persicaria* in all the soil samples may be explained by its ability to continue germination into the summer after herbicide applied in May of the 2 previous years had destroyed all weed seedlings that had appeared by that date. The percentage germination of each species was greater in the glass-house than in the field, but their times of germination were similar in the two conditions.

## Biochemistry Department

### GENERAL PAPERS

- 6.1. HOLDEN, M. (1960). Nucleic acid content of tissues of higher plants. *Biochemists Handbook*. (In the press.)
- 6.2. PIRIE, N. W. (1959). Edible protein from green leaves. *British Vegetarian*, **1**, 229–232.
- 6.3. PIRIE, N. W. (1960). Biological replication considered in the general context of scientific illusion. *New Biol.* **31**, 117–135.
- 6.4. PIRIE, N. W. (1959). Leaf protein as human food. *Lancet*, 28 Nov. 1959, 961–962.
- 6.5. PIRIE, N. W. (1959). Farmer and biochemist versus engineer and doctor. *Proc. Manchester lit. & phil. Soc.* **101**, 96–111.
- 6.6. PIRIE, N. W. (1959). Scientific Writing. *Times lit. Suppl.*, 26 Sept.

### RESEARCH PAPERS

- 6.7. BAWDEN, F. C. & PIRIE, N. W. (1959). The infectivity and inactivation of nucleic acid preparations from tobacco mosaic virus. *J. gen. Microbiol.* **21**, 438–456.

The infectivity of nucleic acid preparations made by disrupting tobacco mosaic virus with phenol was increased, relative to that of intact virus, by



keeping test plants in darkness or at 37° for some time before they were inoculated. The differences in susceptibility to infection of leaves in different physiological states was too great to be explained by differences in the ability of leaf extracts to inactivate nucleic acid preparations *in vitro*. The spontaneous inactivation of the preparations *in vitro* was not prevented by inhibitors of ribonucleases, and most additions to the preparations increased the rate of inactivation. Not all the inactivations are readily explicable on the assumption that the minimal infective unit is a pure nucleic acid built up solely from nucleotides. Leaf sap and saliva are reasonably assumed to inactivate because they contain ribonuclease; also, inactivations by formaldehyde, phenylglyoxal and thiaminase in the presence of thiamine may well reflect reactions with known components of nucleic acids. However, it is less easy to invoke such actions to explain the inactivation by spermine, interferon, some oxidising agents, leaf mitochondria in the presence of some other substances and the greater rate of inactivation *in vacuo* than in air. Although nucleic acid seems essential for infectivity, it seems prudent to suspend judgement about the precise chemical identity of the minimal infective unit.

- 6.8. FESTENSTEIN, G. N. (1959). Substrate specificity of rumen cellulolytic enzymes. *Biochem. J.* **72**, 75-79.

Studies on cell-free extracts of enzymes from sheep rumen showed gluconolactone to be a specific inhibitor of glucose production from carboxymethyl-cellulose, cellulose dextrin and also cellosaccharides from cellobiose to cellopentaose. Inhibition of hydrolysis as measured by reducing sugar estimation is generally less than that in terms of glucose, and it decreases with increasing chain length of substrate.

- 6.9. HOLDEN, M. (1959). Processing of raw cocoa. III. Enzymic aspects of cocoa fermentation. *J. Sci. Fd Agric.* **10**, 691-700.

The changes in the levels of some oxidising and carbohydrate-splitting enzymes of Amelondado cacao bean cotyledons, during both large- and small-scale fermentations, were determined, on samples of beans taken after various periods of fermentation from the top and centre of heaps of different sizes. Enzymes were inactivated sooner in the top layer, where the temperature rise was more rapid, than at the centre. Enzyme levels started to diminish during the period when the beans were dying and continued until, after 3 days' fermentation, little or no activity remained. The results suggest that prolonging fermentation for several days after the beans are dead is neither necessary nor desirable.

A germination inhibitor found in the pulp and testas of beans decreased in amount during ripening and disappeared during fermentation.

- 6.10. MORRISON, J. E. & PIRIE, N. W. (1960). The presentation of leaf protein on the table. *Nutrition*. (In the press.)

The different forms that fresh and dried leaf protein can take, and the problems that each poses in presentation, are discussed. Fifteen different recipes are given; in some the protein is left uncovered and dark green, in others it is encased in a thin batter or pastry coating. The usual starting material for these recipes is the perishable moist protein that is the primary product of the leaf protein extraction process, but a few stable forms of presentation are described.

- 6.11. PIERPOINT, W. S. (1960). Mitochondrial preparations from the leaves of (*Nicotiana tabacum*). 2. Oxidative phosphorylation. *Biochem. J.*

The oxidation of organic acids, catalysed by a sedimentable preparation from tobacco leaves, is accompanied by a disappearance of orthophosphate. Adenosine polyphosphates, hexokinase and glucose stimulate this disappearance, whereas 2:4-dinitrophenol inhibits it. The ratio of phosphate disappearing to oxygen absorbed (P:O ratio) depends on the substrate, and varies between 1 and 2. Nucleotide phosphates and glucose 6-phosphate accumulate during the course of the reaction. The nucleotide phosphates become radioactive when <sup>32</sup>P orthophosphate is present. The oxidation of

organic acids catalysed by these tobacco preparations is accompanied by an evolution of CO<sub>2</sub>. Respiratory quotients vary with the substrate from 0.28 for succinate to 1.5 for citrate.

- 6.12. PIERPOINT, W. S. (1960). Mitochondrial preparations from the leaves of (*Nicotiana tabacum*). 3. Glycollic oxidase and fumarase activity. *Biochem. J.*

Fractions of extracts from tobacco leaves that sediment between 1,000 and 10,000 g oxidise glycollate by a mechanism which does not involve cytochromes, but probably does involve glycollic oxidase. These preparations, however, contain only a small proportion (8%) of the total glycollic oxidase of these extracts; the bulk of it is in the supernatant fraction, from which it is not sedimented by centrifugation at 55,000 g. In contrast, nearly all the fumarase of the extracts is concentrated in the sedimentable fraction, although it is liberated by disruptive treatments. The fumarase, an -SH dependent enzyme, is enough to account for its expected rôle in the fumarate oxidation of these preparations, and seems unlikely to be a rate-limiting step.

### Plant Pathology Department

#### GENERAL PAPERS

- 7.1. BAWDEN, F. C. (1957). Gradations and transitions between pathogenicity and commensalism in infections with plant viruses. *In*: Symposium on "Latency and masking in viral and rickettsial infections", Wisconsin. (Burgess Publishing Co.)
- 7.2. BAWDEN, F. C. (1959). Evolution and viruses. *In*: Symposium on Evolution, Duquesne University, Pittsburgh, Pa.
- 7.3. BAWDEN, F. C. (1959). Viruses: retrospect and prospect. (The Leeuwenhoek Lecture.) *Proc. Roy. Soc. B.* **943**, **151**, 157-168.
- 7.4. BUXTON, E. W. (1959). Factors affecting pathogenic *Fusarium oxysporum* in the rhizosphere of peas. *IXth Int. Bot. Congr., Montreal, Abstracts*: 54-55.
- 7.5. BUXTON, E. W. (DOLING, D. A. & REYNOLDS, J. D.). (1959). Getting the better of the pea wilt. *Fmrs Weekly*, **50**, 88-89.
- 7.6. HARRISON, B. D. (1959). Soil-borne virus diseases of plants. *IX Int. Bot. Congr., Montreal, Abstracts*: p. 152.
- 7.7. KASSANIS, B. & (POSNETTE, A. F.) (1959). Thermotherapy of virus-infected plants. *IX Intern. Bot. Congress, Montreal, Abstracts*: p. 186.
- 7.8. KLECZKOWSKI, A. (1959). Effects of non-ionising radiations on plant viruses. *Proc. New York Acad. Sci.* (In the press.)

#### RESEARCH PAPERS

- 7.9. BANKS, C. J. & NIXON, H. L. (1959). The feeding and excretion rates of *Aphis fabae* Scop. on *Vicia faba* L. *Ent. exp. & appl.* **2**, 77-81.
- (For summary see No. 10.5 below.)
- 7.10. BAWDEN, F. C. (1959). Effect of nitrous acid on tobacco mosaic virus: mutation or selection? *Nature, Lond.* **184**, B.A.27-B.A.29.

The conclusion that nitrous acid causes mutations in tobacco mosaic virus is questioned, because the phenomenon of the number of necrotic local lesions

produced in Java tobacco increasing while the total infectivity of preparations decreases can be duplicated by inoculating plants with mixtures containing tomato aucuba mosaic and tobacco mosaic virus in different proportions.

- 7.11. BAWDEN, F. C. & KLECZKOWSKI, A. (1959). Photoreactivation of nucleic acid from tobacco mosaic virus. *Nature, Lond.* **183**, 503-504.

The free nucleic acid of tobacco mosaic virus is not only more susceptible than the intact virus to inactivation by ultraviolet radiation but also undergoes photoreactivable changes which it is protected against when combined with the virus protein.

- 7.12. BAWDEN, F. C. & PIRIE, N. W. (1959). The infectivity and inactivation of nucleic acid preparations from tobacco mosaic virus. *J. gen. Microbiol.* **21**, 438-456.

(For summary see No. 6.7 above.)

- 7.13. BUXTON, E. W. (1959). The occurrence of *Fusarium* wilt of melon in Britain. *Plant Path.* **8**, 96-97.

From wilted melon plants (*Cucumis melo*, L.), at Chorleywood, Herts, in 1956 and 1957, pathogenic isolates of *Fusarium oxysporum* Fr. f. *melonis* (Leach and Curr.) Snyd, and Hans. were consistently isolated. The fungus wilted four melon varieties, but had no effect on cucumber or vegetable marrow.

- 7.14. BUXTON, E. W. (1959). Production of perfect stage in a nutritionally deficient mutant of pathogenic *Fusarium oxysporum* after ultraviolet irradiation. *Nature, Lond.* **184**, 1258.

Among several isolates of *Fusarium oxysporum* f. *pisi* used for genetical work, one which had mutant nutritional requirements developed small red perithecia. These did not provide asci for over 2 years, but recently asci and ascospores have appeared in the now abundant perithecia. Identified as *Nectria haematococca* Berk. & Br., the cultures yield perithecia from single ascospores or from single spores of the *Fusarium* stage. Crosses were made with other *formae speciales* of *Fusarium oxysporum*, in the hope of extending work on the genetics of pathogenicity. It may also be possible to check cytological details of the parasexual cycle in *Fusarium*, and to investigate taxonomic relationships between *F. oxysporum* and other species of *Fusaria* that have *Nectria* perfect stages.

- 7.15. BUXTON, E. W. & PERRY, D. A. (1959). Pathogenic interactions between *Fusarium oxysporum* and *Fusarium solani* on peas. *Trans. Brit. mycol. Soc.* **42**, 378-387.

The previous observation that the severity of wilt caused by *Fusarium oxysporum* f. *pisi* on pea variety Onward was decreased by simultaneous inoculation with the pea foot-rot pathogen, *F. solani* f. *pisi*, was confirmed by inoculation tests in a glasshouse; the decrease was statistically significant and was increased by increasing the amount of *F. solani* in the inoculum. Inoculating plants with *F. solani* before *F. oxysporum* gave less wilt than inoculating plants with both fungi simultaneously. The decrease of wilt occurred in sterilised soil, showing that other soil micro-organisms are not involved in the phenomenon.

Field observations on a wilt-susceptible pea variety growing in infested soil showed that although *F. solani* entered pea roots earlier than did *F. oxysporum*, the plants were killed by the wilt pathogen. Wilt spread less rapidly along rows of peas from foci of inocula containing both *F. solani* and *F. oxysporum* than from foci of *F. oxysporum* alone. Foot-rot also spread less from a mixed inoculum than from *F. solani* alone.

Differences in the appearance of the macrospores of the two fungi were considered to be the only reliable taxonomic criteria for distinguishing the two species.

**R**

- 7.16. (CADMAN, C. H.) & HARRISON, B. D. (1959). Studies on the properties of soil-borne viruses of the tobacco-rattle type occurring in Scotland. *Ann. appl. Biol.* **47**, 542-556.

Soil-borne viruses of the tobacco-rattle type occur in sandy and peaty soils in many parts of Scotland, and infect many species of crop and weed plants, often only in the roots. They also occur in potato plants that have diseases of the stem-mottle type. The viruses can be distinguished from other soil-borne viruses occurring in Britain by the symptoms they cause in tobacco, *Chenopodium amaranticolor* and French bean.

Some virus cultures (M types) multiplied readily and were easily transmitted by mechanical inoculation, whereas others (NM types) were transmitted mechanically only with difficulty. The behaviour of NM types remained constant during 20 successive subcultures. Only slight differences were noted between the symptoms caused by M and by NM types. A proportion of the single-lesion isolates made from cultures of the M type behaved in every way like NM types: this proportion differed with different parent cultures. Single-lesion isolates that were of the M type mostly caused somewhat different symptoms from their parent culture. All M types that were tested, including one from the Netherlands, were serologically related: however, different cultures, and different samples of the same culture propagated on different occasions, varied in antigenic constitution. Belladonna mosaic virus, described by Smith (1943) from England, was serologically related to tobacco-rattle virus. Infection with each of several M types (including the Dutch culture), protected *Nicotiana sylvestris* plants from the effects of each of the others. NM types also protected *N. sylvestris* from the effects of the Dutch culture, but the latter was subsequently isolated from the tip leaves of such plants. Sap from plants infected with cultures of the M type contained characteristic rod-shaped particles, but none was seen in sap from plants infected with NM types.

In tobacco sap M types had the following properties: thermal inactivation point, 80°-85° C.; dilution end-point, 10<sup>-5</sup>-10<sup>-6</sup>; longevity *in vitro*, over 6 weeks; infectivity survived freezing and precipitation by ammonium sulphate, but not exposure to pH 3. In many of its properties, including the unusual one of failing to show photo-reactivation after ultraviolet irradiation, tobacco-rattle virus resembles tobacco mosaic virus.

Soil-borne viruses occurring in Britain are classified into three groups, exemplified by tobacco necrosis, tomato black ring and tobacco-rattle viruses.

- 7.17. (CADMAN, C. H.) & HARRISON, B. D. (1960). Studies on the behaviour in soils of tomato black ring, raspberry ringspot and arabis mosaic viruses. *Virology*, **10**, 1-20.

When turnip, sugar beet or spinach seedlings were grown for varying periods in soils containing tomato black ring (TBRV) and raspberry ringspot viruses, and then transplanted to virus-free soil, some seedlings became infected in 3 days and many in 9 days. The ease with which TBRV infected and multiplied in roots decreased with increasing age of seedling. The presence of the viruses in soils was shown by growing bait seedlings in them but not by inoculating leaves of test plants with soil extracts. In highly infective soils one bait seedling became infected per 100-200 g. soil. Infectivity of soils was abolished by air-drying for a week at 20° C. and was decreased by freezing at -10° C. It was also abolished by treating soils with pentachloronitrobenzene, tetramethyl-thiuram-disulphide, ethylene dibromide and Nemagon, but not by griseofulvin or by mixing the soil with lime or ammonium sulphate. Infectivity of soils containing TBRV was associated with particles that sedimented through 7 cm. water between 30 seconds and 5 minutes, and to a lesser extent with particles sedimenting in 30 seconds.

Pot experiments showed that seedlings grown in non-infective field soil or autoclaved soil did not become infected when watered with highly infective sap. TBRV became established in autoclaved sand when watered with crude eelworm preparations from infective soils, but not when the sand was mixed with washed roots of naturally infected plants. TBRV became established in non-infective field soil when it was cropped with artificially infected sugar beet. The receptivity of this soil to virus seemed specific to the beet ringspot strain of tomato black ring virus and was abolished by autoclaving.

Evidence is adduced that an agent occurring in soil plays a part in transmission of TBRV, and its possible identity among soil-inhabiting organisms is discussed.

- 7.18. GREGORY, P. H., (GUTHRIE, E. J.) & BUNCE, MAUREEN, E. (1959). Experiments on splash dispersal of fungus spores. *J. gen. Microbiol.* **20**, 328–354.

Splash dispersal (first studied by Faulwetter in 1917) is characteristic of many bacterial plant pathogens and slime-spored fungi. The mechanism of splash was studied in the laboratory under simplified conditions with water drops falling from known heights on to thin films of a suspension of conidia of *Fusarium solani* spread on horizontal glass surfaces. The resulting splash droplets were caught, counted and measured by the naphthol green B slide method (Liddell & Wooten, 1957). Both the total number of droplets produced and of those carrying spores increased as the film thickness decreased, and as the size and velocity of the incident drop increased.

One incident drop 5 mm. in diameter falling on a horizontal film of spore suspension 0.1 mm. thick on a glass surface produced over 5,200 splash droplets, of which over 2,000 carried one or more spores. The sizes of splash droplets ranged from 5  $\mu$  to about 2,400  $\mu$ , and their size distribution was of the log-probability type. The median diameter was 70  $\mu$  for all droplets, and 140  $\mu$  for droplets carrying spores. The median horizontal distances travelled by these droplets in still air was 10 and 20 cm. respectively. Increasing the film thickness to 0.5 and 1.0 mm. decreased the total resulting droplets to 3,500 and 2,100 (1,600 and 500 carrying spores), respectively. Neither median diameter nor median distance of horizontal travel were much altered by varying the diameter of incident drop or film thickness. Droplets of diameters between 164 and 655  $\mu$  tended to travel farther than either smaller or larger droplets. Small spores, such as those of *Gloeosporium album*, *Colletotrichum lindemuthianum* and *Nectria cinnabarina*, were even more readily picked up from suspension than the macroconidia of *Fusarium solani*.

The number of droplets deposited per unit area on a horizontal plane decreased rapidly with increasing distance from point of impact, and in still air few droplets travelled beyond 70 cm.

Splash on a twig bearing conidial fructifications of *Nectria cinnabarina* produced 2,000 spore-carrying droplets, and the sequence of events is shown by high-speed photography.

A splash droplet consists of an intimate mixture of liquid from both the incident drop and the surface film. The larger splash droplets contain spores when either the incident drop or the surface film is a spore suspension. Rain-drops falling at terminal velocity or drops falling more slowly from vegetation can operate the splash dispersal mechanism. Splash in rain or drip from trees may act as a complete dispersal mechanism in still air, or as a "take-off" mechanism leading to dispersal by wind. Both functions are important in plant epidemiology.

- 7.19. HARRISON, B. D. & (CADMAN, C. H.) (1959). Rôle of a dagger nematode (*Xiphinema* sp.) in outbreaks of plant diseases caused by arabis mosaic virus. *Nature, Lond.* **184**, 1624–1626.

Diseases associated with arabis mosaic virus occurred patchily in raspberry, strawberry and white clover crops in widely separated parts of Britain. Pea seedlings became infected when grown in soil from beneath diseased plants, but soil collected outside the patches of diseased plants was not infective. The distribution in soil of a dagger nematode (*Xiphinema* sp.) was correlated with that of diseased plants. When infective soil was fractionated by sieving, the distribution of infectivity in the fractions roughly paralleled that of *Xiphinema*, and when dagger nematodes were separated from the other material in one such fraction the residue was non-infective. Pea seedlings became infected when infested with hand-picked adult male, adult female or larval *Xiphinema* from soil beneath diseased plants. The infectivity of soil was abolished and *Xiphinema* killed by air-drying the soil at 20° C. for a week or by treating it

with various chemicals. It is concluded that *Xiphinema* is a vector of arabis mosaic virus and that in field conditions the spread of the virus is often limited by the distribution of the nematodes.

- 7.20. HARRISON, B. D. & NIXON, H. L. (1959). Separation and properties of particles of tobacco rattle virus with different lengths. *J. gen. Microbiol.* **21**, 569–581.

Tobacco-rattle virus was isolated from tobacco sap by differential centrifugation: the yield was about 50 mg. virus/l. sap. Purified preparations were highly infective, precipitated optimally at pH 4.0–4.5, and contained one electrophoretic component; chemical analysis and the ultraviolet absorption spectrum suggest they contain about 5% nucleic acid and 95% protein. Most rod-shaped particles in purified preparations are 73–77 m $\mu$  or 179–192 m $\mu$  long: all are 25 m $\mu$  wide. These two components were separated by rate zonal centrifugation in sucrose density-gradients: both have the same density in solution as tobacco mosaic virus, and they have sedimentation constants of about 198s and 295s respectively. No differences were found between long and short particles in serological behaviour, electrophoretic mobility or ultraviolet absorption spectrum; apparently they differ little in gross chemical composition. Only the long particles are infective. Particles slightly shorter than 179 m $\mu$  seem non-infective; some of these may be aggregates of two short ones. Short particles rarely aggregate end-to-end at pH 6.8–7.0, but aggregation increases as the pH decreases.

- 7.21. HARRISON, B. D. & NIXON, H. L. (1959). Some properties of infective preparations made by disrupting tobacco rattle virus with phenol. *J. gen. Microbiol.* **21**, 592–599.

Preparations made by treating tobacco rattle virus with phenol are about 5% as infective as the initial virus suspensions when assayed on French bean, but less on tobacco. Virus nucleic acid (NA) seems to be a major constituent of such preparations. By contrast with whole virus, NA preparations lose infectivity when incubated for 20 minutes with 0.02 mg./l. ribonuclease or when stored for a day at 20°. NA preparations contain threads about 1 m $\mu$  in diameter, but very few or no virus rods. The infectivity of NA preparations is little affected by high-speed centrifugation for periods in which more than 95% of whole virus is sedimented. Ultraviolet-irradiated NA preparations are photo-reactivable, although irradiated preparations of whole virus are not. NA preparations were only infective when made either from purified virus suspensions or from frozen and clarified saps, which contained infective rod-shaped particles 179–192 m $\mu$  long. Phenol treatment of purified non-infective particles 73–77 m $\mu$  long yielded non-infective preparations.

- 7.22. KASSANIS, B. Comparison of the early stages of infection by intact and phenol-disrupted tobacco necrosis virus. *Virology*. (In the press.)

Preparations of a tobacco necrosis virus disrupted by phenol were as infective as the parent virus preparation when the two were compared in pH 7 phosphate buffer and about one fifth as infective when compared in water. No virus particles could be detected in the disrupted preparations by electron microscopy, and the preparations were rapidly inactivated by dilute solutions of pancreatic ribonuclease, harmless to the intact virus. At 20° the preparations became inactive in 1–4 days.

Some of the changes detectable in infected bean leaves occur sooner with inoculum of disrupted virus than with intact virus. The infective centres initiated by disrupted virus start to increase their resistance to inactivation by ultraviolet radiation immediately after inoculation, whereas those initiated by intact virus do so only after a lag period of 2–3 hours, and newly formed virus becomes detectable 2–4 hours sooner when the inoculum is disrupted virus. The very first lesions produced by each type of inoculum appear simultaneously, but those produced by disrupted virus reach their final number sooner than those produced by intact virus. The peak rate at which lesions appear is about 4 hours earlier with inoculum of disrupted than with intact virus, and the lesions produced are more uniform in size.

- 7.23. KASSANIS, B. & TINSLEY, T. W. (1958). The freeing of tobacco tissue cultures from potato virus Y by 2-thiouracil. *Proc. 3rd Conf. Potato Virus Diseases*, Lisse-Wageningen, 1957.

Thiouracil inhibits the multiplication of tobacco mosaic and some other viruses in inoculated leaves, but there is no record of it affecting the amount of virus already present in leaves. Tobacco tissue cultures infected with potato virus Y, however, were freed from the virus by maintaining them for periods of 3 weeks or more on media containing 100 mg./l. of thiouracil. Progenies from these cultures are still free from detectable virus 1 year after the treatment. Spraying thiouracil on growing plants systemically infected with potato virus Y also decreased the virus content of leaves but did not free them from infection. In addition to intrinsic differences between the leaves and tissue cultures, the failure to free infected leaves may be that they contain more than 10 times as much virus as do tissue cultures.

- 7.24. KLECZKOWSKI, A. (1959). An electrophoretic study of the mechanism of precipitin reactions: variation in reversibility. *Immunology*, **2**, 97-103.

Antibodies to human serum albumin differ from one antiserum to another in the degree of firmness and reversibility of combination with the antigen. These differences are reflected in different behaviours during electrophoresis of soluble antigen-antibody compounds. Molecules of each kind of antibody seem also able to combine with the antigen in more than one way.

- 7.25. KLECZKOWSKI, A. (1959). Aggregation of the protein of tobacco mosaic virus with and without combination with nucleic acid. *Virology*, **7**, 385-393.

The protein produced by splitting tobacco mosaic virus with alkali has a smaller electrophoretic mobility at pH 7 than the virus, and recombining the protein with the nucleic acid increases its mobility almost to that of the original virus. Nevertheless, the nucleic acid does not seem to contribute appreciably to the surface potential either of the original virus or of the particles of the reconstituted nucleoprotein, because the surface potential of disks and cylinders produced by the protein alone when it is aggregated at pH 7 by exposure to ultraviolet radiation also have a surface potential approaching that of the original virus. This and other evidence suggests that the surface charge density of the protein fragments is non-uniform and that when the fragments form cylindrical aggregates the parts of the surface that are oriented outward are the most negatively charged.

- 7.26. KLECZKOWSKI, J. & KLECZKOWSKI, A. (1959). Effect of infection with bacteriophage on electrokinetic potential of host bacteria. *J. gen. Microbiol.* **21**, 308-311.

Infection with bacteriophage increased the electrophoretic mobility of pea nodule bacteria (*Rhizobium leguminosarum*) at pH 7. The increase occurred at about the middle of the latent period, suggesting that the bacterial surface alters at this stage of infection.

- 7.27. MACFARLANE, I. & LAST, F. T. (1960). Some effects of *Plasmodiophora brassicae* Woron. on the growth of the young cabbage plant. *Ann. Bot. Lond. N.S.* (In the press.)

When clubroot galls developed on cabbage inoculated with *Plasmodiophora brassicae* Woron. the distribution of dry matter in the plant was altered. As soon as clubbed roots were visible the stem to root ratio diminished with time until the clubs rotted. After clubs appeared the increase in root weight was nearly all from growth of the clubroot gall, and the rate of growth of tops correspondingly diminished. Succulence of the shoot, water content per unit dry weight, was unaffected.

Increase in total leaf area closely paralleled that of total dry weight. It was slower in diseased plants, and attained a lower limit than in healthy ones. From the 35th day after inoculation onwards diseased plants had fewer and smaller leaves, and their leaves opened more slowly, one new leaf unfolding every 9 days on diseased plants against one every 4 days on healthy plants.

Leaves of diseased plants were both smaller and thinner than those in corresponding positions on healthy plants.

The relationship between the absorbing system, on the one hand, and the assimilating and transpiring system, on the other, was greatly altered; the dry weight of fibrous root per unit leaf area was decreased after infection from 1.20 to 0.79 mg./cm.<sup>2</sup> 20 days after inoculation and from 1.64 to 0.38 mg./cm.<sup>2</sup> 82 days after inoculation.

Though infection consistently lowered net assimilation rate, on the average by about 15% of the control value, this decrease was never statistically significant.

Increases in the number of spores in the inoculum progressively decreased the dry weights of tops and fibrous roots, and sometimes increased the dry weight of clubs.

Delaying inoculation increased the initial growth rate of the galls, and sometimes their final size. The extent to which plants were damaged depended more on how long they had been infected than on age at inoculation.

- 7.28. NIXON, H. L. & HARRISON, B. D. (1959). Electron microscopic evidence on the structure of the particles of tobacco rattle virus. *J. gen. Microbiol.* **21**, 582-591.

The structure of tobacco rattle virus (TRV) was studied by examining with the electron microscope: (1) shadowcast mounts of particles partly degraded by treatment with alkali, sodium dodecyl sulphate, or phenol; and (2) unshadowed mounts on thin carbon film of particles treated with solutions of lanthanum nitrate, uranyl acetate, osmium tetroxide, phosphomolybdic acid or phosphotungstic acid.

The particles are tubular, with a central hole of approximately 4 m $\mu$  diameter and an outside diameter which varies from 17 to 25 m $\mu$  according to treatment. Next to the central hole, which can be filled with lanthanum nitrate or uranyl acetate, is a region 1-1.5 m $\mu$  thick, which stains heavily with osmium tetroxide, phosphomolybdic and phosphotungstic acids. The rest of the particle stains lightly with uranyl acetate, phosphomolybdic and phosphotungstic acids, and shows transverse bands 2.5 m $\mu$  apart. It is suggested that these bands may represent a helical structure similar to that of tobacco mosaic virus, which TRV resembles in many respects.

- 7.29. NIXON, H. L. & WOODS, R. D. (1959). The structure of tobacco mosaic virus protein. *Virology*, **10**, 157-159.

High-resolution electron microscopy of particles of reaggregated tobacco mosaic virus protein, made by spraying a suspension of the particles in neutral phosphotungstate, gives images which are in remarkably good agreement with the structure of the particles inferred from X-ray-diffraction patterns. The particles are crossed by a regular system of bands spaced 2.5 m $\mu$  apart, which are thought to represent the individual turns of the protein helix, and short fragments standing on end show a 16-fold radial symmetry, corresponding to the number of sub-units to be found in a single turn of the helix. Detailed examination of the image of a particle surface often shows small areas in which the arrangement of individual sub-units can be seen.

- 7.30. PERRY, D. (1959). Studies on the mechanism underlying the reduction of pea wilt by *Fusarium solani* f. *pisi*. *Trans. Brit. mycol. Soc.* **42**, 388-396.

The mechanism underlying the decrease caused by *Fusarium solani* f. *pisi* in the severity of pea wilt was studied by examining sites in the soil and in the host where the two fungi might interact.

*F. solani* produced no substance *in vitro* that inhibited spore germination or growth of *F. oxysporum*, and there was no evidence that the two competed to the detriment of *F. oxysporum* either in the rhizosphere of peas or in the soil. Some water extracts of foot-rot lesions contained a substance inhibitory to the germination of *F. oxysporum* spores, but it could not always be demonstrated. No inhibition was caused by exudates from or in extracts of pea roots infected with *F. solani*.

*F. solani* colonised the epidermis and outer cortex of pea roots more rapidly and more extensively than did *F. oxysporum*. Three days after inoculation



with *F. solani*, pea roots respired 25% more than uninoculated ones. The physical structure and biochemical nature of the cortex was altered by infection by *F. solani*, so it is concluded that the only part of the infection process of *F. oxysporum* that is changed by the presence of *F. solani* is during passage through the cortex.

- 7.31. WATSON, MARION A. (1958). The specificity of transmission of some non-persistent viruses. *Proc. Xth Int. Congr. Ent.* 1958, 215-219.

When leaves infected with potato virus Y and other non-persistent viruses were exposed to ultraviolet light the infectivity of their expressed saps was reduced, suggesting that the viruses were more concentrated in the epidermis than elsewhere in the leaves.

Non-persistent viruses are transmitted by aphids much more readily after 1 or 2 minutes' feeding on infected leaves than after longer times. With irradiated leaves there was no greater ability after short than after long infection feeding times.

*Brevicoryne brassicae* (L.) does not transmit cauliflower mosaic virus optimally after 2 minutes infection feeding, and its ability to transmit is not affected by irradiation of the infected leaf on which it feeds. *Myzus persicae* (Sulz.), on the other hand, transmits cauliflower mosaic in the same manner as other non-persistent viruses, and irradiation lowers its ability to transmit after short infection feeds.

Potato virus C is serologically related to potato virus Y, and both are similarly affected by ultraviolet irradiation. But potato virus Y is readily aphid-transmissible and potato virus C, according to previous workers, not at all. Thus the ability of a virus to be transmitted by an aphid is not correlated with physical or chemical properties nor with distribution in the leaf or susceptibility to secretions by aphids. Present evidence suggests that it perhaps depends on the virus particle having some special group, probably only a small part of its total constitution, that combines specifically with some component of the aphid's mouth parts.

- 7.32. WATSON, MARION A. & SINHA, R. C. (1959). Studies on the transmission of European wheat striate mosaic virus by *Delphacodes pellucida* Fabricius. *Virology*, 8, 139-163.

Several races of *Delphacodes pellucida* were isolated that transmit European wheat striate mosaic virus with varying degrees of efficiency. The length of the incubation period of the virus in the vectors increased as the proportion of plant-hoppers that were able to transmit infection decreased.

Efficient races of *D. pellucida* transmitted virus to a high proportion of their progeny, but nymphs of inefficient races inherited little or no virus, even from infective mothers.

Congenitally infective inbred lines of planthoppers did not become more infective after feeding on infected plants, but planthoppers that did not inherit virus could usually acquire it with about the same efficiency as that of the parent race. Females of an efficient race that became infective as a result of feeding on infected plants as nymphs, 15 days before mating, transmitted virus to eggs laid from 10 to 15 days after mating, but females fed on infected plants only during mating usually did not transmit to their progeny, though they were able to infect plants within 15 days of acquiring virus.

Infective mothers that fed on infected plants as nymphs had 40% fewer progeny than did those fed on healthy plants. Some embryos died in the egg at a comparatively late stage of development, and it is probable that the virus was pathogenic to them. The poor reproductive ability of infective females tends to eliminate the virus from colonies that are unable to renew their infectivity by feeding on infected plants.

## Nematology Department

### BOOKS

- 8.1. FRANKLIN, M. T. & HOOPER, D. J. (1959). *Plants recorded as resistant to root-knot nematodes* (Meloidogyne spp.). Farnham Royal: Commonwealth Agricultural Bureaux, 33 pp.

- 8.2. GOODEY, J. B., FRANKLIN, M. T. & HOOPER, D. J. (1959). *Supplement to the nematode parasites of plants catalogued under their hosts, 1955-58*. Farnham Royal: Commonwealth Agricultural Bureaux, 66 pp.

GENERAL PAPERS

- 8.3. GOODEY, J. B. (1959). Data to be considered, observed and where possible, reported upon when presenting descriptions of new species. *Nematologica*, **4**, 211-216.
- 8.4. WALLACE, H. R. (1959). Sugar-beet eelworm—the position today. *Sugar Beet Rev.* **28**, 83-85.
- 8.5. WALLACE, H. R. (1959). Chrysanthemum eelworm. *Quart. Bull. nat. Chrys. Soc.* **37**, 5-10.
- 8.6. WALLACE, H. R. (1959). Further observations on chrysanthemum eelworm. *Quart. Bull. nat. Chrys. Soc.* **39**, 7-12.

RESEARCH PAPERS

- 8.7. FENWICK, D. W. & WIDDOWSON, E. (1959). The emergence of larvae from free eggs of the potato-root eelworm, *Heterodera rostochiensis* Woll. *Ann. appl. Biol.* **47**, 140-149.

A technique for doing hatching experiments on eggs freed from cysts is described. The form of the hatching response resembled that of eggs within cysts, but free eggs responded to the hatching stimulus more quickly. Cysts had to be soaked before extracting the eggs from them for hatching, because eggs from dry cysts, or from cysts opened or cracked before soaking, did not respond to diffusate. When free eggs and whole cysts were exposed to the same graded series of dilutions of diffusate, the log concentrations of hatching factor derived from plotting the hatching curves agreed closely.

- 8.8. FRANKLIN, M. T. (1959). *Nacobbus serendipiticus* n.sp., a root-galling nematode from tomatoes in England. *Nematologica*, **4**, 286-293.

A new species of *Nacobbus*, found causing galling of the roots of tomato in a nursery in Berkshire, is described. This is the first time a member of this genus has been found outside the United States.

- 8.9. FRANKLIN, M. T., THORNE, G. & OOSTENBRINK, M. (1960). Proposal to stabilise the scientific name of the cereal root-eelworm (Class Nematoda). *Bull. zool. Nom.* 76-85.

The arguments for using the name *Heterodera major* instead of *H. avenae* for the cereal-root eelworm are given and the use of the two names in the literature is analysed. The name *avenae* Wollenweber, 1924, is proposed in preference to *major* O. Schmidt, 1930. A new-type has been designated and is characterised.

- 8.10. GOODEY, J. B. (1959). The excretory system of *Paraphelenchus* and the identity of the hemizonid. *Nematologica*, **4**, 157-159.

Keeping specimens of *P. myceliophthorus* in water at 4° for 3-4 months made it possible to see that, besides a ventral uninucleate cell, the excretory system has an anterior and posterior tubule in the right lateral chord. The hemizonid appears to be a ventrolateral commissure of the nervous system.

- 8.11. HESLING, J. J. (1959). The emergence of *Heterodera rostochiensis* from single cysts. *Nematologica*, **4**, 126-132.

New cysts of *Heterodera rostochiensis* were sieved into four size grades. The egg contents of the largest cysts varied widely. The range of egg contents decreased with decreasing cyst size, and frequency diagrams for egg contents

showed increasingly pronounced peaks. Despite random selection of the batches of 50 cysts studied in each size grade, the frequency distribution of egg contents for all grades taken together was skew and showed many cysts with between 60 and 200 eggs. Cysts in the three smaller size grades gave a higher percentage hatch than those in the largest grade. The least variable hatch was given by the second size grade (0.401–0.556 m.). Over 65% of cysts of this size range gave a hatch of over 80%.

- 8.12. HESLING, J. J. (1959). Some observations on the cereal-root eelworm population of field plots of cereals with different sowing times and fertiliser treatments. *Ann. appl. Biol.* **47**, 402–409.

In autumn 1953 an experiment was begun to follow changes in the cereal-root eelworm population of small plots in Shropshire. The plots were cropped with either oats, wheat, barley or rye, sown in the autumn and spring, and some plots had fertiliser. Each plot received the same treatment for 3 years; in the 4th year an indicator crop of spring oats was grown on all the plots.

Under rye and autumn-sown wheat the eelworm population fell to a level which permitted a good oat crop in 1957. Autumn-sown wheat, barley and rye gave lower eelworm populations than their spring-sown counterparts, but autumn-sown oats was the most efficient host. The order of host efficiency was oats (best), barley, wheat, rye. The eelworm populations were usually higher on plots receiving fertiliser. All oat plots, and spring-sown barley plus fertiliser, produced populations which severely damaged the 1957 oat crop.

- 8.13. SHEPHERD, A. M. (1959). Increasing the rate of larval emergence from cysts in hatching tests with the beet eelworm *Heterodera schachtii* Schmidt. *Nematologica*, **4**, 161–164.

The rate of emergence of larvae from cysts of *Heterodera schachtii* can be increased up to 4 times after 2 weeks by using small sieves made of polythene tubing and nylon material, which allow the cysts to be aerated all round. The rate of hatch in water is also slightly increased when sieves are used, but the total hatch is not significantly different in the two techniques. Adding fungistatic and bacteriostatic substances to the hatching medium increases further the rate of emergence and the total hatch. This may be because micro-organisms competing for oxygen are suppressed or because hatching is directly stimulated.

- 8.14. SHEPHERD, A. M. (1959). Testing populations of beet eelworm, *Heterodera schachtii* Schmidt, for resistance-breaking biotypes using the wild beet (*Beta patellaris* Moq.) as indicator. *Nature, Lond.* **183**, 1141–1142.

Of 8 populations of *H. schachtii* tested for their ability to infect *Beta patellaris*, single cysts able to do so occurred on 1 plant in each of 2 populations and 2 cysts on a plant in a third. Thus, resistance-breaking biotypes seem not to occur on the same scale as with *H. rostochiensis*, but the ability of individual females to multiply is important.

- 8.15. SHEPHERD, A. M. (1959). The invasion and development of some species of *Heterodera* in plants of different host status. *Nematologica*, **4**, 253–267.

The host-parasite relationship between *Heterodera schachtii* and 13 plant species in the families *Chenopodiaceae* and *Cruciferae* was examined. Third-stage larvae, though often few, were found in all plant species, but no fourth stage larvae were found in *B. webbiana*, *B. patellaris*, *B. procumbens*, *Hesperis* or *Matthiola*. No male was found in *B. procumbens*, *Hesperis* or *Matthiola*, and only one in *B. webbiana*. No female was found in *B. procumbens*, *B. patellaris*, *Hesperis* and *Matthiola*, very few in radish, *Chenopodium album* and *Brassica sinapis*, and only one in *B. webbiana*. *B. trigyna* was a better host than sugar beet, and the susceptible species of *Chenopodiaceae* were more efficient hosts than the susceptible species of *Cruciferae*. When hatched larvae of *H. schachtii*, *H. rostochiensis* and *H. göttingiana* were added to pots with plants

not producing a hatching factor, all species were invaded, though sometimes by very few larvae. The presence of host roots did not affect the number of larvae of *H. schachtii* invading the roots of pea, a plant that does not produce a hatching factor for this eelworm.

Factors affecting the host-parasite relationship are discussed, and a modification of Jones's classification of plants into categories of host status is suggested. The relationship is continuous rather than discontinuous, and is best expressed as a frequency. For example, when tested with an inoculum of Q larvae, P reached maturity and reproduced on variety X of plant Y. The ratio P/Q is the frequency in question, and may be 0 where X is a marginal host and Q is small, but may have a definite value when Q is large.

- 8.16. SHEPHERD, A. M. & WALLACE, H. R. (1959). A comparison of the rates of emergence and invasion of beet eelworm, *Heterodera schachtii* Schmidt and pea-root eelworm, *Heterodera göttingiana* Liebscher. *Nematologica*, **4**, 227-235.

Experiments with cysts in sand under controlled moisture conditions indicate that beet eelworm has a higher emergence rate than pea-root eelworm. The invasion rate of pea-root eelworm is considerably higher than that of beet eelworm. These differences in behaviour may account for the few larvae that emerge from pea-root eelworm cysts in experiments *in vitro*; despite this, the high invasion rate populations may still increase substantially. Sampling for larvae of pea-root eelworm in a field plot containing peas showed emergence rate to be relatively low. Two experiments with beet eelworm are described showing that soil moisture may influence the production of the hatching factor from cress roots and that the rate the hatching factor diffuses through sand almost saturated with water is about 0.5 cm./day.

- 8.17. WALLACE, H. R. (1959). Movement of eelworms. V. Observation on *Aphelenchoides ritzema bosii* on florists' chrysanthemums. *Ann. appl. Biol.* **47**, 350-360.

Adults of *Aphelenchoides ritzema bosii* tend to migrate up the stems of chrysanthemum plants in a water film with no downward flow, probably a negative geotropic response. A current of water down the stem opposes this upward movement. Mobility in different environments on the plant was determined. It was greatest in thick films of water on tissues with many epidermal hairs, as at the top of the stem and on the undersurface of leaves. Ciné films of movement in thick and thin films showed that the type of locomotion in these two environments differed greatly. Invasion of leaves via stomata was observed and the mode of entry is described. Observations on emergence of eelworms from the leaf, their movement inside the leaf and spread through the mesophyll are discussed. They emerge via the stomata, chiefly on the undersurface. When the leaf is wet about 50% of the eelworms emerge in the 1st hour. In wet weather many eelworms were recovered from the surfaces of leaves, and the eelworm probably spreads mostly in these conditions.

- 8.18. WALLACE, H. R. (1959). The movement of eelworms in water films. *Ann. appl. Biol.* **47**, 366-370.

The beet eelworm, *Heterodera schachtii*, and the chrysanthemum eelworm, *Aphelenchoides ritzema bosii*, were observed in water films, and wave formation, wave frequency, speed and type of locomotion noted. (1) The wave frequency and speed of beet eelworm is greater in thin films than in thick; for chrysanthemum eelworm, speeds and wave frequencies were greatest in thick films; (2) chrysanthemum eelworm is more active than beet eelworm, as indicated by the higher wave frequency and speed; (3) both species form asymmetrical waves in thick films, the waves decreasing in amplitude as they pass along the body—symmetrical waves are formed by both species in thin films; (4) progress is more uniform in thin films than in thick films, where forward movement occurs as the head moves across the axis of progression. A hypothesis is given to show how the surface tension forces acting on an eelworm in a thin film determine mobility.

- 8.19. WALLACE, H. R. (1959). Further observation on some factors influencing the emergence of larvae from cysts of the beet eelworm, *Heterodera schachtii* Schmidt. *Nematologica*, **4**, 245-252.

The emergence curve for beet eelworm cysts in sand at controlled moisture content resembles that *in vitro*. The smaller the particle size, the higher the optimum suction for emergence. There does not appear to be a limiting suction for emergence as was suggested previously. At the optimum suction the rate of emergence may decrease with particle size. As larval emergence progresses, carbon dioxide probably accumulates and inhibits further hatch and emergence. Emergence from cyst and movement through soil pores are fundamentally the same phenomenon and obey the same factors influencing locomotion. A hypothesis is given to show how emergence is influenced by the soil environment.

- 8.20. WALLACE, H. R. (1960). Movement of eelworms. VI. Observations on the influence of soil type, moisture gradients and host plant roots on the migration of the potato-root eelworm, *Heterodera rostochiensis* Wollenweber. *Ann. appl. Biol.* **48**. (In the press.)

In a sandy loam, a heavy clay and a peat soil, the optimum crumb sizes for larvae of potato-root eelworm to move were 150-250  $\mu$  and 250-400  $\mu$ . Mobility in the clay and sandy loam, where there is an optimum suction for movement, was similar, but in the peat mobility increased with suction and the optimum suction was not established. Larvae may be able to move in peat at high suctions because friction between the larvae and the peat crumbs is less than in clay or sand. In a moisture gradient in sand, larvae moved to the wet end, and the number doing so increased with the steepness of the gradient. Larvae moved in sand 150-250 $\mu$  diameter distances between 2 and 3 cm./day, depending on suction. As pore size increases, any upward movement in a moisture gradient is opposed by falling under gravity. In sand, where the body diameter approximates to the width of the pore, there is no response to a moisture gradient or gravity. Host roots also counteract the response to a moisture gradient; the degree of orientation to roots increased with the time the roots are in the sand. Direct observation on larvae newly emerged from cysts, in the presence of host-plant roots, suggests that larvae orientate themselves away from the root and do not reach the root by random movement. Many of the movements of eelworms seem explicable by considering the relationship between pore size, eelworm diameter and water distribution. A diagram is given showing the relationship between movement and soil factors.

- 8.21. WINSLOW, R. D. (1959). A note on anhydrotetrone acid as a hatching agent of the beet eelworm, *Heterodera schachtii* Schm. *Nematologica*, **4**, 237-238.

### Insecticides and Fungicides Department

#### GENERAL PAPERS

- 9.1. WAY, M. J. (1958). The use of insecticidal seed dressings. *Rep. Rothamst. exp. Sta. for 1958*, 214-222.
- 9.2. WAY, M. J. (1959). Development of insect resistance to insecticides. *N.A.A.S. Quart. Rev.* **46**, 60-67.

#### RESEARCH PAPERS

- 9.3. BARDNER, R. (1959). Insecticidal control of wheat bulb fly larvae. *Plant Path.* **8**, 47-52.

Methods of control tested over several years included seed dressings, combine-drilling of insecticide with the seed at the time of sowing, dusting the plants and soil surface with insecticide, and spraying insecticide on the foliage.

Seed dressings of aldrin, dieldrin and heptachlor were the most effective. A very high rate of application, equivalent to 1.92 lb. active ingredient per acre, was only moderately better than 0.29 lb/acre. Combine-drilling of aldrin and dieldrin dusts at 1.5 lb/acre were effective, but less so than the seed dressings. Both seed dressings and combine-drilling have to be applied at sowing, before it is known whether the severity of the attack will justify the expense of the insecticide.

Dieldrin dust broadcast at 5 lb./acre just before the start of the attack gave promising results, but organo-phosphorus sprays applied at various times during the attack were the least successful of all the methods tried.

- 9.4. ELLIOTT, M., OLEJNICZAK, J. S. & GARNER, J. J. (1959). Laboratory-scale molecular distillation of the pyrethrins. *Pyrethrum Post*, 5 (2), 8-18.

The conditions of molecular distillation to give a pale-coloured distillate containing 60-70% total pyrethrins were determined. The undistilled residue contains less than 10% pyrethrins, and no thermally isomerised pyrethrins I and II can be detected.

- 9.5. LAST, F. T. (1959). Effect of cotton leaf resistance factors on the spread of *Xanthomonas malvacearum* (E.F.Sm.) Dowson in the Gezira, Sudan. *Emp. Cott. Gr. Rev.* 36 (3), 187-195.

Knight's cotton leaf resistance factors retarded the spread of *X. malvacearum* in field crops in 1956-58 to much the same extent as they retard the development of individual lesions. Of the factors and combinations of factors tested, B<sub>2</sub> was the least effective in preventing the spread of disease and B<sub>2</sub> and B<sub>3</sub> combined were intermediate, while combinations with B<sub>6m</sub> were the most effective. B<sub>2</sub>B<sub>6m</sub> and B<sub>2</sub>B<sub>3</sub>B<sub>6m</sub> varieties did not differ appreciably from each other.

Recently-irrigated plants of the B<sub>2</sub>B<sub>3</sub> derivative (BAR 14/25) of Domains Sakel (*Gossypium barbadense*) became more diseased after a rainstorm than plants unirrigated for at least 6 days.

- 9.6. LAST, F. T. (1959). Leaf infection of cotton by *Xanthomonas malvacearum* (E.F.Sm.) Dowson. *Ann. appl. Biol.* 47, 647-657.

*X. malvacearum* spread more rapidly along vascular tissue than into mesophyll when inoculated to the main veins of susceptible cotton leaves. The extent of spread varied with the concentrations of inocula, tissue age and cotton variety.

Increasing concentrations of inocula accelerated the initial spread of disease.

Bacteria spread more rapidly in young leaves than in old—increasing age greatly decreased disease in the mesophyll. The initial invasion was quicker in young leaves of young plants than in young leaves of old plants.

Three types of behaviour, according to the host's reaction, distinguish Knight's resistance factors: (a) where *X. malvacearum* spread extensively along veins and into mesophyll of plants containing B<sub>3</sub> and B<sub>5</sub>; (b) where it was restricted to the point of inoculation in plants containing B<sub>4</sub>, B<sub>9</sub> and combinations with B<sub>6m</sub>; and (c) where it spread along veins but not appreciably into mesophyll in varieties containing B<sub>2</sub> and B<sub>2</sub>B<sub>3</sub>.

From this and 4 other different types of tests, factors B<sub>2</sub> and B<sub>3</sub> seem to increase mesophyll resistance, but only B<sub>2</sub> gives appreciable vascular resistance. Further, the vascular bundles in varieties with B<sub>2</sub> seem to be surrounded by an additional "barrier" which resists *X. malvacearum*.

- 9.7. LAST, F. T. (1959). Effect of *Xanthomonas malvacearum* (E.F.Sm.) Dowson on cotton yields. *Emp. Cott. Gr. Rev.* 37.

As many cotton plants were infected by *Xanthomonas malvacearum* spread from infectors sown simultaneously with the rest of the plot as from infectors planted 3 weeks later. Yields, however, were only affected by bacteria from the earlier-sown infectors. Weights of seed cotton decreased by 19% (without affecting the Ginning-out-Turn), and harvest was significantly delayed.

- 9.8. MACFARLANE, I. & LAST, F. T. (1960). Some effects of *Plasmodiophora brassicae* Woron. on the growth of the young cabbage plant. *Ann. Bot. N.S.* (In the press.)

(For summary see No. 7.27 above.)

- 9.9. WARD, J., GILLHAM, E. M. & POTTER, C. (1959). A thermal preference method of bioassay of the toxicity of insecticidal films to houseflies. *Bull. ent. Res.*

Methods used to confine insects to the test-surface during exposure to insecticidal deposits are reviewed, and their limitations discussed.

A temperature preference method of inducing houseflies to remain on a treated surface is described, and the apparatus is illustrated. The treated surface forms the floor of a chamber; it is maintained at a higher temperature than the walls and lid. The flies are introduced with a plunger device.

The variance in mortality among groups of insects given the same exposure was determined in three experiments. In the first, plates sprayed with a crystalline suspension of DDT were used immediately after spraying, and the variance was high. In the second, the same set of plates was used 24 hours later, and the results were not significantly heterogeneous. In the third, plates carrying a deposit of DDT in liquid paraffin were used, and the results were just significantly heterogeneous at the 5% level of probability. The heterogeneity is thought to come from variations in the degree of activity of the houseflies while on the test-surface; it was too small to affect probit lines obtained with the apparatus.

Nine successive experiments, in which the LD-50 of DDT/liquid paraffin on glass plates was determined, gave a range of results from 0.65 to 1.45  $\mu\text{g./cm.}^2$  of DDT and probit line slopes in the range 2.8–6.2. One of the lines was significantly heterogeneous.

In seven separate experiments to determine the toxicity of DDT emulsion sprayed on cabbage leaves, the probit lines were too steep for calculation by the normal method, but all the points fell between parallel lines intersecting the 50% mortality abscissa at 1.4 and 2.7  $\mu\text{g./cm.}^2$ —no greater than the usual variation in resistance between different cultures of test-insects.

The behaviour of some other insect species in the test chamber was observed. The apparatus would probably be suitable for use with *Blatella germanica*, but some species failed to respond to the temperature gradient and others were too small for the apparatus as described.

- 9.10. WAY, M. J. (1959). The effects of freezing temperatures on the developing egg of *Leptohylemyia coarctata* Fall. (Diptera, Muscidae) with special reference to diapause development. *J. Insect Physiol.* (In the press.)

The later stages of diapause in the egg of *L. coarctata* are completed rapidly at  $-20^{\circ}\text{C.}$  to  $-24^{\circ}\text{C.}$  At  $-24^{\circ}\text{C.}$  diapause is completed about 180 times faster than at  $-6^{\circ}\text{C.}$  and about 80 times faster than at  $3^{\circ}\text{C.}$  These results suggest that there are at least two phases in diapause development—an initial synthesis, perhaps of neurohormone, which will not occur at  $-18^{\circ}\text{C.}$  to  $-24^{\circ}\text{C.}$  This is followed by a process ending in release of the synthesised material which is greatly accelerated by relatively short exposures to  $-20^{\circ}\text{C.}$  to  $-24^{\circ}\text{C.}$ ; longer exposures kill the eggs probably because they freeze.

- 9.11. WAY, M. J. (1959). Experiments on the mode of action of dieldrin seed dressings against seedling attack by the larval frit fly, *Oscinella frit* L. *Ann. appl. Biol.* **47**, 802–808.

In glasshouse experiments and in a small field trial fewer newly hatched frit-fly larvae were killed when dieldrin-treated seed was sown deeply than when sown  $\frac{1}{4}$ – $\frac{1}{2}$  inch deep. Shallow sowing probably puts the insecticide where the larvae from eggs in the soil are likely to meet it before they attack the plant. Larvae hatching from eggs on the plant are probably unaffected by contact action. There was little evidence that frit-fly larvae are killed inside the oat shoot by systemic action of dieldrin translocated from the seed. This is not from any factor specific to oats because frit-fly larvae also survived in wheat from seed dressed with doses of dieldrin that can kill almost all wheat bulb fly larvae (*Leptohylemyia coarctata* Fall.) by systemic action.

- 9.12 WAY, M. J. (1959). Experiments on the mode of action of insecticidal seed dressings especially against *Leptohylemyia coarctata* Fall., Muscidae, the wheat bulb fly. *Ann. appl. Biol.* **47**, 783–801.

Certain chlorinated hydrocarbon insecticides applied as seed dressings to wheat can kill wheat bulb fly larvae either by contact or by systemic action. Shallow sowing favours contact action because the larvae are likely to pass close to the treated seed on their way to attack the shoot. It is not known whether the larvae are killed directly by contact action or whether they die of starvation after being deterred. Wheat bulb fly larvae tunnel within the shoot and may damage it severely before they are killed by the systemic action of aldrin or dieldrin seed-dressings. Close contact between the seed-dressing and the seed apparently favours the uptake of dieldrin and aldrin by the plant: systemic action is also favoured by sowing the seed shallowly and by increasing the dose of insecticide adhering to the soil.

Onion fly larvae *Delia antiqua* Meig. enter the onion bulb close to the position of the seed, and thus are likely to be killed by contact with the insecticide on the seed. There was no evidence that dieldrin seed-dressings act systemically against onion fly larvae.

- 9.13. WAY, M. J. (1959). The effect of temperature, particularly during diapause, on the development of the egg of *Leptohylemyia coarctata* Fallen (Diptera: Muscidae). *Trans. Roy. Ent. Soc.* **3**, 351–364.

The eggs of *L. coarctata* Fallen are usually laid on bare soil in August and hatch during the following January–March.

The embryo apparently becomes fully developed during pre-diapause morphological development which merges imperceptibly into the diapause stage. Diapause ends by January, and the eggs begin to hatch shortly afterwards when the temperature is above 0° C.

Although eggs near the surface experienced much greater temperature fluctuations than those deeper in the soil, all hatched at the same time.

Within the normal temperature range, the lower and upper limits for the different stages of development are: pre-diapause morphological development—between 0°–3° C. and over 30° C.; diapause physiological development—6° C. and 12° C.; post-diapause development (re-activation and hatching)—0° C. and over 30° C. The optimum constant temperature for diapause development is about 3° C. The egg can develop through all stages at constant temperatures between 3° C. and 12° C.; the optimum is about 7° C. Development is accelerated in some eggs by transferring them in the middle of their diapause to 30° C. or 35° C., for 1–7 days, but it is stopped or reversed by an interval of 2–4 weeks at 20° C.

Development can proceed at the beginning of diapause, and to a lesser extent towards the end, at a temperature above the upper limit for the intervening stages. This suggests that the temperature optimum for diapause may vary as development proceeds.

Diapause development at –20° C. may be as fast as at 3° C. This is not ecologically significant, but may help towards understanding the physiology of diapause.

## Entomology Department

### GENERAL PAPERS

- 10.1 BARNES, H. F. (1959). Gall midges (Cecidomyiidae, Diptera) living at the base of grasses. *J. Sports Turf Res. Inst.* **9**, 430–436.
- 10.2 GERARD, B. M. (1959). Earthworms in farm and garden. *Turf for Sport*, **3** (6), 11–14.
- 10.3 MELLANBY, K. (1959). Life at low temperatures. *Advanc. Sci., Lond.*, **15**, 409–417.



RESEARCH PAPERS

- 10.4 BANKS, C. J. (1959). Experiments with suction traps to assess the abundance of Syrphidae (Diptera), with special reference to aphidophagous species. *Ent. exp. & appl.* **2**, 110-124.

Preliminary information on the abundance of some common species of Syrphidae was obtained from the catches in 5 suction traps during the summers of 1951, 1952 and 1953. Six of the eight "abundant" species were aphidophagous.

The numbers of the individual species recorded varied from year to year, with the time of year and from place to place.

Although the catches could not be correlated with the immediate weather, the large differences between them could be associated with the differences in the general weather of the 3 years. Syrphidae were few in the spring, although most species showed a small peak of numbers then, and maximum catches of nearly all species were in August.

At two localities the abundance of individual species and the composition of the catches differed greatly. Where the vegetation was varied, Syrphidae were more diverse and more abundant than where it was uniform. Some species occurred in one locality but not in the other. The size and composition of the catch were not obviously affected by the kind of vegetation immediately around a trap.

- 10.5 BANKS, C. J. & NIXON, H. L. (1959). The feeding and excretion rates of *Aphis fabae* Scop. on *Vicia faba* L. *Ent. exp. & appl.* **2**, 77-81.

The feeding and excretion rates of nymphs of *Aphis fabae*, feeding on young leaves of *Vicia faba*, were studied, using host plants grown in water culture and made radioactive with <sup>32</sup>P. Little sap was ingested at first, but the rate of ingestion increased rapidly between 12 and 16 hours. The maximum rate of feeding was estimated at 0.2 mg. sap/hour, an uptake of 59% of the mean body weight of the insects per hour. The results are discussed in relation to other recent work on aphid feeding and excretion.

- 10.6 BARNES, H. F., MILLER, B. S. & ARNOLD, M. K. (1959). Some factors influencing the emergence of overwintering Hessian Fly larvae. *Ent. exp. & appl.* **2**, 224-239.

Overwintering fully-fed hessian fly larvae in puparia respond to temperature and relative humidity changes progressively faster as the normal time of pupation and emergence in the spring approaches. Frost does not speed up emergence.

A constant temperature of 15° or 20° C. at 95% R.H. is recommended for producing midges for experiments from overwintering hessian fly puparia.

- 10.7 BARNES, H. F., MILLER, B. S. & ARNOLD, M. K. (1959). The susceptibility of Atle wheat to attack by the Wheat Blossom Midges. *Plant Path.* **8**, 143-144.

Atle is sometimes as susceptible as other varieties.

- 10.8 DOBSON, R. M. (1959). Preliminary observations on the behaviour of the adult Wheat Bulb Fly *Leptohylemyia coarctata* (Fall.) using the field-cage-marking technique. *Anim. Behav.* **7**, 76-80.

The behaviour of wheat bulb fly was observed over two 24-hour periods during July 1957, using individually marked flies confined in a large field cage standing in a wheat crop. Flies occurred on the fabric of the cage, on the wheat, on flowering grasses and less often on various weeds (some of which were abundant), and on the ground. Differences in the proportions of the sexes on the cage and on various parts of the wheat plants reflected differences in their behaviour.

Females were very active shortly before nightfall, but after dark both sexes

became quiescent (although some activity including flight persisted) and adopted a characteristic "head-upward" posture. At daybreak activity was resumed.

The technique could be developed into a valuable one for studying behaviour in the field.

- 10.9. DOBSON, R. M. (1959). Notes on the taxonomy and occurrence of *Carpophilus* Stephens. (Col. Nitidulidae) associated with stored products. *Ent. mon. Mag.* **95**, 156–158.

Type specimens of *Carpophilus dimidiatus* (F.) and *Carpophilus mutilatus* Er. are designated and *C. luridus* Murray is shown to be a synonym of *C. mutilatus* Er. Recent records of *Carpophilus* species found on stored produce are tabulated.

- 10.10. DOBSON, R. M. (1960). Hatching of the egg in the Cabbage Stem Flea Beetle *Psylliodes chrysocephala* (L.) (Col. Chrysomelidae). *Ent. mon. Mag.*

The egg bursting mechanism and manner of hatching of the flea beetle *Psylliodes chrysocephala* (L.) are described.

- 10.11. DOBSON, R. M. (1960). The immature stages of the Flea Beetles *Psylliodes cuprea* (Koch) and *Psylliodes chrysocephala* (L.) (Col. Chrysomelidae.) *Ent. mon. Mag.*

The immature stages of *Psylliodes chrysocephala* (L.) and *Psylliodes cuprea* Koch are described, figured and compared.

- 10.12. FRENCH, R. A. (1959). Migration records 1958. *Entomologist*, **92**, 164–176.

- 10.13. (ENTWISTLE, P. F.), JOHNSON, C. G. & (DUNN, E.). (1960). New pests of Cocoa (*Theobroma cacao* L.) in Ghana following applications of insecticides. *Nature, Lond.* **184**, 2040.

- 10.14. LONG, D. B. (1959). Observations on adult weight and wing area in *Plusia gamma* L. and *Pieris brassicae* L. in relation to larval population density. *Ent. exp. & appl.* **2**, 241–248.

Crowding of lepidopterous larvae decreases weight and wing dimensions in the resulting adults and possibly contributes towards migration by its effect on form and function. The ratio of total weight to wing area is often termed "wing loading", and this ratio increases with different species of flying creatures of increasing weight.

The effect of larval crowding on body weight and wing loading in *Plusia gamma* L. and *Pieris brassicae* L. was studied by contrasting freshly emerged adults from solitary and crowded larval cultures. Crowding decreased weight and wing area disproportionately, thereby decreasing wing loading. Within each species and sex wing loading decreased with decreasing emergence weight, and this partly explained the effect of crowding on wing loading.

In *P. gamma* the fore-wing was larger than the hind-wing. Nevertheless, the fore-wing was the more affected by crowding, and more in the female than the male. Temperature also affected weight and wing area. In solitary cultures warmer weather principally decreased male weight and hind-wing area, whereas fore- and hind-wing areas of the female were more affected, consequently wing loading decreased in the male and increased in the female.

In *P. brassicae* the hind-wing is the larger, and decreased more with crowding. Crowding did not appear to affect the sexes differently, but the results suggested that the effect may be accentuated in the male and lessened in the female at lower temperatures. As with *P. gamma*, warmer temperatures decreased weight and wing area in *P. brassicae*, but wing area was the more affected, so wing loading increased in both sexes. Crowding, however, accentuated the effect of temperature on weight, thereby decreasing wing loading. Thus, in both species decreases in weight and wing area with warmer temperatures were not identical with those of crowding.

- 10.15. MELLANBY, K. (1960). Acclimatisation affecting the position of the cold and heat death points of larvae of *Aedes aegypti* (L.). *Bull. ent. Res.* **50**, 821-823.

In experiments with *Aedes aegypti* (L.), fourth-stage larvae bred at 30° C. survived exposure to 0.5° C. for 7 hours, but none recovered after exposure for 17 hours, although nearly all those from the same culture that had been acclimatised for 24 hours to 18° or 20° C. did so. No such effect followed acclimatisation at 10° C., at which larvae are in chill coma. Larvae acclimatised at 18° C. survived exposure to 5° C. for longer than did those from 30° C. The thermal death point, for a 1-hour exposure, was 42° C. for larvae acclimatised at 30° C. but rose to 44° C. for larvae acclimatised to 37° C. It is concluded that the effects of high or low extremes of temperature may be modified by a brief period of acclimatisation at a less extreme temperature.

- 10.16. MELLANBY, K. (1960). The biological importance of the invertebrate soil fauna. *Soils & Fert.* **23**, 8-9.

Invertebrates metabolise more slowly than warm-blooded vertebrates. Laboratory measurements of invertebrate metabolism may give results much higher than those obtaining in the soil. The biological importance of vertebrates, which is related to their metabolic rate, may easily be overestimated.

- 10.17. MELLANBY, K., FRENCH, R. A. & RICHES, J. (1960). Herbicide spray and frit fly attack on oats. *Ent. exp. & appl.* **2**, 319-320.

Oats sown 11 April 1959 had a similar tiller attack by frit fly in areas sprayed with CMPP and in unsprayed areas.

- 10.18. MURPHY, P. W. (1959). Soil faunal investigations. *Rep. For. Res.* for 1958.

- 10.19. RAW, F. (1959). Estimating earthworm populations by using formalin. *Nature, Lond.* **184**, 1661.

Earthworm populations estimated by using dilute formalin to make the worms come out of the soil are compared with estimates obtained by using potassium permanganate solution and by hand-sorting soil samples. Formalin is more efficient than potassium permanganate solution, but less efficient than hand-sorting soil samples, except for estimating *Lumbricus terrestris*. This species burrows too deeply for soil sampling to be practicable, but seems to be extracted very efficiently by formalin.

- 10.20. RAW, F. (1960). Field studies on wheat bulb fly infestations. *Ann. appl. Biol.* **48**, 145-155.

Two experiments on commercial farms in Essex studied the effect of tillage, cultivation and seed rate on wheat bulb fly infestation and the effect of infestation on yield. Heavier infestations developed on rough fallows and those cultivated during the oviposition period than on smooth fallows and those not cultivated during the oviposition period. These results confirmed those of an earlier experiment done at Rothamsted. At each level of infestation more larvae survived on plots sown at 3 bushels/acre than on plots sown at  $\frac{3}{2}$  or 1 bushel/acre. Although some plots had a high larval population, no effect of infestation on yield was observed even at the lower seed rates. This is attributed to early sowing. The extent to which the cultural treatments studied can be used to control wheat bulb fly infestations is discussed.

- 10.21. STEPHENSON, J. W. (1958). Aldrin controlling slug and wireworm damage to potatoes. *Plant Path.* **8**, 53-54.

Applying 1¼% aldrin dust at either 480 lb./acre or 240 lb./acre immediately before planting significantly decreased damage by slugs and wireworms.

- 10.22. TAYLOR, L. R. (1959). Abortive feeding behaviour in a black aphid of the *Aphis fabae* group. *Ent. exp. & appl.* **2**, 143-153.

A black *Aphis* sp. on *Tropaeolum* can be separated, morphologically, from *A. fabae* Scop. In controlled experiments this aphid, both winged and wingless

less forms, actively selects *Vicia faba* as a host plant, settles to feed and reproduce, but always dies prematurely. Offspring also soon die. The aphid is unable to take up plant sap from beans. The behaviour associated with host-plant selection is not adjusted to its feeding requirements.

10.23. TAYLOR, L. R. (1960). Mortality and viability of insect migrants high in the air. *Nature, Lond.*

Insects were collected by nets at heights from 1,000 to 5,000 feet, between 09.00 and 16.00 hours in June, July, August and September, at Cardington, Bedfordshire. 97% of the 1,610 insects caught were alive and undamaged. Living offspring were obtained from:

- Cabbage aphid, *Brevicoryne brassicae* L.
- Peach-potato aphid, *Myzus persicae* Sulz.
- Bean aphid, *Aphis fabae* Scop.
- Frit fly, *Oscinella frit* L.
- The hessian fly group, *Mayetiola* sp., possibly *destructor* Say.

This establishes that insects migrating at high levels in normal summer weather over England are alive and viable.

10.24. TAYLOR, L. R. (1960). The distribution of insects at low levels in the air. *J. anim. Ecol.*

Records of insects caught on sticky traps and in nets at several heights up to 30 feet were examined and the density distribution estimated in relation to height.

The insects concerned are all small; thrips, aphids, psocopterons, frit-fly and coccinellids. Their distribution appears to be consistent with that found for similar insects at greater heights.

Density diminishes regularly as height increases, except that gradients may change at 20-25 feet and between 30 and 50 feet.

These are probably the levels up to which such small insects fly in still air, and the predominance of winds above their flight speed is an over-riding influence that produces the generally regular profile when all weather conditions are taken together. Suction-trap catches, which show a mean density for all insects 3 times as great at 5 as at 30 feet, support this conclusion.

Larger insects, e.g., moths, behave differently; suction-trap catches show they can select a particular height of flight.

Catches on sticky traps were converted to densities by using a general wind-speed profile, which although open to some criticism is not sufficiently in doubt to affect the main conclusions.

The curve distributions of insect numbers often produced when sticky-trap catches are plotted against height and give maximum values at different heights on different occasions or for different species, are a product of the wind-speed and insect-density profiles, i.e., a function of the type of trap used rather than of the behaviour of the insect.

10.25. ZAHER, M. A. & LONG, D. B. (1959). Some effects of larval population density on the biology of *Pieris brassicae* L. and *Plusia gamma* L. *Proc. R. ent. Soc. (A)* **34**, 97-109.

Although crowding in *P. gamma* prolonged the pupal period, it shortened the larval and pre-oviposition periods so much that the total developmental period from hatching to egg-laying was shorter than under solitary conditions. In both larval treatments a long larval period was followed by a relatively short pupal period, and a short preoviposition period by the laying of many eggs. The subsequent fecundity was greater in crowded cultures, though under both conditions of culture more than one-half of the eggs were laid by slightly more than 20% of the females.

In *P. brassicae* the shorter larval period in crowded cultures was followed by a shorter pupal, but preoviposition period and the total developmental period was, however, less, with fewer eggs in a cluster.

In both species the mean egg weight was lighter in crowded cultures. The adult lifespan of the male in *P. gamma* and of the female in *P. brassicae* tended to be prolonged by crowding. Crowding larvae of *P. gamma* did not influence either the percentage of sterile females or their lifespan.

### Bee Department

#### GENERAL PAPERS

- 11.1. BAILEY, L. (1959). Recent research on the natural history of European Foul Brood disease. *Bee World*, **40**, 66-70.
- 11.2. BUTLER, C. G. (1959). Queen substance. *Bee World*, **40**, 269-275.
- 11.3. FREE, J. B. (1959). The transfer of food between the adult members of a honeybee community. *Bee World*, **40**, 193-201.
- 11.4. FREE, J. B. & SPENCER-BOOTH, YVETTE. (1959). Temperature regulation by honeybees. *Bee World*, **40**, 173-177.
- 11.5. SIMPSON, J. (1960). Problems of swarming behaviour. *Rep. cent. Ass. Brit. Beekeep. Ass.*

#### RESEARCH PAPERS

- 11.6. BAILEY, L. (1959). An improved method for the isolation of *Streptococcus pluton*, and observations on its distribution and ecology. *J. Insect. Path.* **1**, 80-85.

*Streptococcus pluton* was isolated, on a special agar, more easily and in greater abundance from dried smears of mid-gut contents of honeybee larvae with European Foul Brood disease than from fresh material. *S. pluton* remains viable in such smears for at least 15 months at room temperature. Viable *S. pluton* is smeared over cell walls of brood comb in the faeces of infected larvae that survive and pupate. *S. pluton* was isolated from larval remains from colonies suspected of having European Foul Brood disease from Tanganyika, Norway, California and Southern England.

- 11.7. BAILEY, L. & LEE, D. C. (1959). The effect of infestation with *Acarapis woodi* (Rennie) on the mortality of honeybees. *J. Insect. Path.* **1**, 15-24.

In laboratory and field tests infestation increased mortality of the oldest and most heavily infested bees only. This corresponds with lack of signs of infestation in heavily infested colonies except at the end of winter when the population is senile. Restricted development of brood in summer was associated with increased infestation.

- 11.8. BUTLER, C. G. (1959). The source of the substance produced by queen honeybee (*Apis mellifera* L.) which inhibits development of the ovaries of the workers of her colony. *Proc. R. ent. Soc. Lond. (A)*. **34**, 137-138.

Development of the ovaries of the worker bees of a colony is normally inhibited by a substance produced by the queen and distributed over her body surface, from which the workers obtain it. The same or an analogous substance normally inhibits workers from rearing queens. Both the substance which inhibits queen rearing and that which inhibits ovary development are produced in the queen's mandibular glands.

- 11.9. BUTLER, C. G. (CALLOW, R. K. & JOHNSON, NORAH C.). (1959). Extraction and purification of "queen substance" from queen bees. *Nature, Lond.* **184**, Suppl. 24, 1871.

A method of extracting and purifying queen substance in ethanol extracts of queens' heads is described. The waxy crystals, which inhibit queen rearing by worker bees, appear to be an  $\alpha\beta$ -unsaturated carboxylic acid, containing an unconjugated carbonyl group.

- 11.10. FREE, J. B. (1959). The effect of moving colonies of honeybees to new sites on their subsequent foraging behaviour. *J. agric. Sci.* **53**, 1-9.

Groups of colonies were moved to crops: before any flowers were open, when 5-15% were open, when flowering was near its peak. Colonies moved to the crop after flowering had begun provided more pollinators than those moved earlier.

- 11.11. FREE, J. B. & SPENCER-BOOTH, YVETTE. (1959). Observations on the temperature regulation and food consumption of honeybees (*Apis mellifera*). *J. exp. Biol.* **35**, 930-937.

Bees were kept in groups ranging from 10 to 200 bees, at temperatures from 0° to 40° C. At 40° bees in groups of 200 had a higher mortality than those in smaller groups. At 25°-35° mortality was low and similar in all groups. Below 25° the larger a group, the longer it survived. Temperatures of all groups increased with that of their environment; the larger a group, the higher its temperature. The difference between the temperature of a group and that of its environment decreased as the temperature of the latter increased, until at 35°-40° the temperatures of groups of all sizes were slightly below those of the environment. Between 20° and 40° the percentage of bees in a group which were clustering was directly related to the size of the group; bees in small groups scarcely clustered at all. At or below 15° about the same high percentage of bees clustered in all groups. As environmental temperature decreased food consumed per bee increased. Very little water was taken at 25° or lower, but at 35° and above a lot was taken.

- 11.12. SIMPSON, J. (1959). Variation in the incidence of swarming among colonies of *Apis mellifera* throughout the summer. *Insectes soc.* **6**, 85-99.

Observations were made throughout the summer of the quantity of adult bees and brood, the numbers of queen-cell cups and the incidence of swarm preparations, in colonies. Comparison of these data with long-term averages of temperature and nectar availability showed that in the summer months the season of maximum breeding and swarming was more closely related to food supply than to temperature or length of day. The possibility that a physiological rhythm was also involved could not be excluded. Swarm preparations appeared to be a cause of, rather than caused by, a decline in brood rearing or the ratio of brood to adult bees.

- 11.13. SIMPSON, J. (1959). The male genitalia of *Apis* species. *Nature, Lond.* **185**, 56.

The male genitalia of honeybees from tropical Africa appear identical with those of European bees (*A. mellifera*), but both differ from the closely allied species *A. indica* (from Ceylon). Specimens from intermediate regions have not yet been obtained. The male genitalia of *A. dorsata* and *A. florea* are also described.

- 11.14. SIMPSON, J. (1960). The functions of the salivary glands of *Apis mellifera*. *J. Ins. Physiol.* (In the press.)

Worker bees dissolve dry sugar, clean their queen's body and possibly soften or lubricate materials being chewed, with the watery secretion of their labial glands. A small amount of oil is produced and accumulates in these glands: what little is discharged adheres to the tongue hairs and is not mixed with the food: its function is obscure. Secretion of the mandibular glands is discharged by a movement of the hypopharyngeal plate, acting through a tendon, on the mouth of the gland. It is a suspension of acid globules, insoluble in water and in some lipid solvents but soluble in alcohol, glycol, etc. The secretion of the mandibular glands is not used in chewing. Salivary invertase comes only from the hypopharyngeal glands.

- 11.15. (CALLOW, R. K., JOHNSTON, NORAH C.) & SIMPSON, J. (1959). 10-hydroxy- $\Delta^2$ -decenoic acid in the honeybee (*Apis mellifera*). *Experientia*, **15**, 421.

Comparison of physico-chemical properties showed that the secretion of the mandibular glands of worker bees consists largely of 10-hydroxy- $\Delta^2$ -decenoic acid, the main lipoid component of larval food.

### Statistics Department

#### BOOK

- 12.1. YATES, F. (1960). *Sampling methods for censuses and surveys*. 3rd Edition. London: Griffin.

A new chapter describing the application of electronic computers to the analysis of censuses and surveys has been added. A general system for the specification of survey analyses on such computers is described.

#### GENERAL PAPERS

- 12.2. HEALY, M. J. R. (1960). The uses of automatic computers in studies of growth and physique. *Proc. 1959 int. Conf. med. Electronics*. (In the press.)
- 12.3. SIMPSON, H. R. (1960). The analysis of survey data on an electronic computer. *Proc. 1959 int. Conf. med. Electronics*. (In the press.)
- 12.4. YATES, F. (1959). Obituary: Wilfred Leslie Stevens. *J. R. statist. Soc. A*, **122**, 403-404.
- 12.5. YATES, F. (1959). Mathematics in biological and agricultural research. *Proc. Liverpool Math. Conf.* (In the press.)
- 12.6. YATES, F., HEALY, M. J. R. & LIPTON, S. (1959). L'analyse des expériences répétées sur calculatrice électronique. *Rev. Stat. appl.* **7**, 47-75. (Translated from *J. R. statist. Soc. B*, **19**, 234-254, (1957).)

#### RESEARCH PAPERS

- 12.7. (ALEXANDER, W. H.) & LEECH, F. B. (1960). A quantitative evaluation of some factors affecting the non-fatty solids of cows' milk. *J. Dairy. Res.* **27**, 19-32.

The statistical analysis of data from problem and control herds showed that most of the differences in level of S.N.F. in these two groups could be accounted for by differences in the proportions of old cows, by breed differences, by differences in the total cell count of the milk and by a seasonal effect that occurred only in the problem herds. The effect of conception late in lactation is shown.

The herd age and average calving intervals are largely under the control of the owner, but there is no evidence that high cell counts can be controlled effectively by means other than lowering the herd age. Clinical mastitis was clearly associated with high cell counts, and tended to be most frequent in old cows, so that lowering the herd age would be expected to affect three factors—age, cell count and mastitis—all of which tend to lower S.N.F.

The remaining effect (seasonal/feeding) was unchanged by improvements in feeding suggested to the owners; its total effect was small, but it merits further investigation.

- 12.8. BOYD, D. A. (1960). Sampling surveys in agriculture. *N.A.A.S. quart. Rev.* **12**, 108-115.

The article deals mainly with those types of survey with which members of the National Agricultural Advisory Service are likely to be associated, and

describes the kind of information which can be obtained from them. The relative advantages of postal surveys and surveys by personal visit are discussed, sampling procedures are outlined and hints are given on drawing up the questionnaire and collecting and recording the information.

- 12.9. CHISCI, G. C. & LESSELLS, W. J. (1960). Relative productivity of six local varieties of lucerne in Northern Italy. *Euphytica*, **9**.

The yields of 6 varieties of lucerne are compared in 6 experiments in Northern Italy; cuts were taken over a 3-year period. Each variety possessed an advantage in the locality of its origin; otherwise differences between varieties were consistent from one centre to another.

- 12.10. CHURCH, B. M. (1959). Fertiliser practice surveys in England and Wales. *Agriculture, Lond.* **66**, 389–395.

Methods used in fertiliser practice surveys in England and Wales are described. The value of information on how farmers use fertilisers, to the advisory services, to farmers themselves and to industry, is illustrated by discussing results from a series of surveys in East Shropshire. Some information on recent trends in cereal manuring in England and Wales is summarised.

- 12.11. CHURCH, B. M. (GOUGH, H. C. & SOUTHEY, J. F.). (1959). Soil sampling procedure for potato root eelworm cysts. *Plant Path.* **8**, 146–151.

A series of co-operative experiments to determine the sampling errors when estimating field populations of *Heterodera rostochiensis* Woll is described. Estimates are made of the accuracy obtained from different samples, and methods are recommended for routine sampling. Although sampling errors are greater than with cereal-root eelworm, much the same recommendations apply. The results show the advantage of systematic sampling on a rectangular grid and of taking repeat samples from the same points when following trends.

- 12.12. CHURCH, B. M. & (WOODFORD, E. K.). (1960). A pilot survey of herbicide practice in N.W. Oxfordshire. *Farm Economist*. (In the press.)

This paper describes a pilot survey of 83 farms, made by the A.R.C. Unit of Experimental Agronomy, Oxford, to discover how much information could be obtained on herbicide practice and its effects by interviewing farmers.

- 12.13. HEALY, M. J. R. (1959). The analysis of field experiments on an electronic computer. *Biomet. Z.* **1**, 210–214.

A summary of the methods of analysis of experiments on the Rothamsted electronic computer, together with a catalogue of the programmes at present available.

- 12.14. (LESLIE, P. H.) & GOWER, J. C. (1960). The properties of a stochastic model for the predator-prey type of interaction between two species. *Biometrika*. (In the press.)

A stochastic model of a predator-prey system is studied by numerical methods.

In the model considered the birth-rates of both species are kept constant throughout, any change in the numbers of the predator affects the death rate of the prey. The main concern is to investigate the behaviour of the system in the region of the stationary state, and to estimate the chances of random estimation for one or other of the two species. Theoretical formulae are obtained for first approximations to the variances and covariances of the two species numbers for a system in the region of the stationary state.

A set of parameters governing the system is chosen so that the population numbers of both species are sufficiently large to make the chances of random extinction of either species negligible. Numerical results obtained lead to variances and covariances that agree well with the theoretical approximations. A further contrast with theory is made between the mean recurrence time of particular population numbers, and satisfactory agreement is found here too.



Some numerical results are obtained and discussed for systems where the chance of random extinction is no longer negligible.

The remainder of the paper discusses various ways in which the probability of both species persisting may be increased.

- 12.15. PATTERSON, H. D. (1960). A further note on a simple method for fitting an exponential curve. *Biometrika*, **47**.

A method is presented for estimating  $\rho$  in the equation  $y = \alpha - \beta\rho^x$  for up to  $n = 12$  equally spaced values of  $x$  from the root of a quadratic equation in  $r$  with coefficients given by linear functions of the  $y_x$ . Unless  $\rho$  is very small and  $n$  large these estimates have very high efficiencies and are good approximations to the least-squares estimates  $r$ . The agreement with  $r$  is particularly good when  $n = 4$ . Details are also given of a similar method for the case in which  $x = 0, 1, 2$  and  $4$ .

- 12.16. PATTERSON, H. D. (1959). An experiment on the effects of straw ploughed in or composted on a three-course rotation of crops. *J. agric. Sci.* (In the press.)

This paper deals with the results of a long-term experiment on the effects of wheat straw (ploughed in or composted) and NPK fertilisers on yields of barley, sugar beet and potatoes grown in a three-course rotation.

All the effects of straw obtained in this experiment can be attributed to changes in the supplies of available nutrients; no benefits appear to have been obtained through improved soil structure or increased organic matter content. The most important changes in nutrient supplies were: (1) losses of soil nitrogen or nitrogen fertiliser immobilised by the straw, and (2) gains of potassium from the straw.

When the straw was ploughed in directly about 0.08 cwt. N fertiliser applied to crops for each ton of straw was sufficient to overcome losses in yield due to immobilisation of nitrogen. The effects of the potassium in the straw were about the same as the effects of equivalent amounts of K fertiliser added to the crop.

Compost made with NP fertiliser and straw and ploughed in with K fertiliser gave very poor results. All the N fertiliser (0.15 cwt. N for each ton of straw) was either lost through drainage or immobilised by the straw; also more than one-half of the potassium in the straw was lost in composting.

There is some evidence that the immobilised nitrogen added to the store of slowly available nitrogen; none of this became available, however, in the first or second year after application.

- 12.17. PATTERSON, H. D. & LIPTON, S. (1959). An investigation of Hartley's method for fitting an exponential curve. *Biometrika*, **46**, 281-292.

The efficiencies and biases of the estimates of  $\rho$  in the equation  $y = \alpha - \beta\rho^x$ , obtained by the method of Hartley, were examined numerically using general formulae derived in an earlier paper by Patterson. Whereas Hartley's method generally leads to estimates having relatively high efficiencies and small biases, and can therefore be regarded as adequate for many purposes, the same conclusion does not hold for similar methods sometimes used in place of the original Hartley method.

- 12.18. WESTMACOTT, M. H. & (LINEHAN, P. A.) (1960). Measurement of uniformity in seed bulks. *Proc. 1959 Conf. Seed Testing Assoc.* (In the press.)

A new measure of imperfection in the mixing of different batches of seed is developed.

- 12.19. (WITHERS, F. W.), (PECK, E. F.) & LEECH, F. B. (1959). A survey of diseases and losses in dairy cattle in Wiltshire and Devonshire.

The relation of disease to culling and wastage in Wiltshire and a part of Devon is analysed, and estimates are obtained of depreciation in the market value of cows affected by the more common diseases. These estimates lead

to a rough assessment of the relative economic importance of the diseases studied.

The principal causes of morbidity and their incidence are summarised. Some differences between counties and between the two years are shown and discussed.

Characteristics of the herds in the two areas and within the major land-use regions of each area are shown, and estimates are obtained of the use of tuberculin testing, S19 vaccination and milk recording in different types of herd and in different areas.

- 12.20. YATES, F. (1959). Methods of sampling the population. Contribution to: Immunological and Haematological Surveys: Report of a Study Group. *World Health Organ. tech. Rep. Ser.* no. 181.

Suitable methods of sampling human or animal populations are described. It is suggested that for many immunological and haematological surveys it is preferable to select typically contrasting areas, instead of attempting to cover the whole population.

- 12.21. YATES, F., LIPTON, S., (SINHA, R. & DAS GUPTA, P.). (1959). An exploratory analysis of a large set of  $3 \times 3 \times 3$  fertiliser trials in India. *Emp. J. exp. Agric.* **27**, 263-275.

The Rothamsted electronic computer was used to make a combined analysis of 238 single replicate  $3 \times 3 \times 3$  trials on rice, done in the State of Bihar, India, in the 1956-57 crop season. The 3 blocks of each replicate were on 3 separate fields in a village; this had little effect on the estimates of the interactions or experimental error. The experiments attained satisfactory accuracy and showed good responses to N and P, and smaller responses to K, with little interaction between the factors. There were considerable variations in response from thana to thana. The responses showed little correlation with the soil classification (clay, loam or sandy).

- 12.22. (YEO, D.) & SIMPSON, H. R. (1959). The effect of repeated insecticidal applications on a natural tsetse population. *Bull. ent. Res.* (In the press.)

Using the mathematical model of a tsetse population previously described (*Biometrics*, **14**, 159-173, (1958)), the effect of insecticidal applications is examined and the numerical results obtained are discussed.

## Field Experiments

### GENERAL PAPERS

- 13.1. GARNER, H. V. (1959). Fertiliser responses and optimum dressings. *J. Inst. Corn Merch.* **7**, 39-43.
- 13.2. GARNER, H. V. (1959). The oldest experiment in the world. *Discovery*, **20**, 296-301.

An account of Broadbalk Field, Rothamsted.

## Woburn Experimental Station

- 15.1. THOROLD, C. A. (1959). Methods of controlling black-pod disease (caused by *Phytophthora palmivora*) of *Theobroma cacao* in Nigeria. *Ann. appl. Biol.* **47**, 708-715.

No trees resistant to black-pod disease were found within the local population of Amelonado types, but resistance may occur among a wider range of varieties.

Satisfactory control of black-pod was obtained with copper fungicides, applied with either hand-sprayers or a power-sprayer. The monetary return depends on yield level, rather than on disease incidence or on spraying costs. It is recommended that spraying should be done when the potential yield is 12 or more pods per tree.

**Dunholme Field Station**

GENERAL PAPERS

- 16.1. ADAMS, S. N. (1959). Sugar beet fertiliser experiments in 1958. *Min. Agric. Sugar Beet Res. & Educ. Comm. Pap.* 528.
- 16.2. ADAMS, S. N. (1959). Present views on sugar beet manuring. *Brit. Sugar Beet Rev.* **27**, 111-113.
- 16.3. ADAMS, S. N. (1959). Manuring next year's sugar beet. *Brit. Sugar Beet Rev.* **28**, 77-78.
- 16.4. BYFORD, W., CORNFORD, C. E., DUNHAM, E. C. W., DUNNING, R. A., & HULL, R. (1959). Sugar beet disease investigations, 1958-59. *Min. Agric. Sug. Beet. Res. & Educ. Comm. Pap.* 527.
- 16.5. HULL, R. (1959). Spraying sugar beet to control virus yellows. *Brit. Sugar Beet Rev.* **27**, 114.
- 16.6. HULL, R. (1959). Virus yellows was decreased by spraying. *Brit. Sugar Beet Rev.* **28**, 24.
- 16.7. HULL, R. (1959). Spraying controlled aphids and yellows. *Brit. Sugar Beet Rev.* **28**, 62.
- 16.8. HULL, R. (1959). Beet yellows virus; its transmission and effect on sugar beet. (*In Report of the sugar beet virus disease committee of the I.I.R.B.*). *Rep. 22nd Winter Cong. int. Inst. Sugar Beet Res. Brussels 1959*, 273-287.
- 16.9. HULL, R. (1960). Sugar beet diseases. Revised edition. *Min. Agric. Bull.* 142.
- 16.10. HULL, R. (1959). Sugar beet yellows in Great Britain, 1958. *Plant Path.* **8**, 145.

RESEARCH PAPERS

- 16.11. ADAMS, S. N. (1960). The value of calcium nitrate and urea for sugar beet and the effect of late nitrogenous top-dressings. *J. agric. Sci.* (In the press.)

28 experiments on sugar beet in 1956-58 compared the effect of ammonium sulphate, calcium nitrate and urea applied to the seedbed before sowing at rates which supplied nil, 0.6 and 1.2 cwt. N/acre; also 0.6 cwt. N/acre applied at the end of June.

Average responses in sugar yield were low, 0.6 cwt. N/acre being enough to give maximum sugar production. The heavier nitrogen dressing increased the yield of tops.

Calcium nitrate and urea raised sugar yield as effectively as ammonium sulphate. No fertiliser damaged germination, and urea containing 4.5% biuret used for top-dressing in 1956 caused no damage. Calcium nitrate and, to a lesser extent, urea produced more tops than ammonium sulphate.

Nitrogen in the seedbed raised sugar yield as effectively as a split dressing. Leaching of nitrogen in a wet summer is therefore not important to sugar beet. Late nitrogen, on the other hand, never harmed sugar production if some had been given to the seedbed.

- 16.12. BAKER, P. E. (1960). Aphid behaviour on healthy and yellows virus-infected sugar beet. *Ann. appl. Biol.* **48**, 2.

*Myzus persicae*, *M. ascalonicus*, *Aphis fabae* and *Aulacorthum* species, when caged on sugar-beet leaves in the glasshouse preferred yellows virus-infected leaves to healthy ones; they chose those with the strongest symptoms, on which they bred more rapidly and lived longer than on green leaves. *M. persicae* behaved similarly on whole plants in the glasshouse. The previous

host influenced the aphid's preference. Differences between the multiplication rates of aphids on healthy plants in inbred sugar-beet varieties were eliminated or reversed by infection with yellows virus.

Spraying healthy plants with either sugar solutions or hydrolysate of casein increased the multiplication rate of *M. persicae*, but much less than did virus infection.

- 16.13. GIBBS, A. J. (1959). Docking disorder. *Plant Path.* **8**, 93-94.

Docking disorder of sugar beet has symptoms similar to acid soil injury, but occurs seasonally on sandy soils with pH value above 6.5. It seems not to be caused by a pathogen but by unusual physical or chemical condition in the soil.

### Soil Survey of England and Wales

- 17.1 AVERY, B. W., STEPHEN, I., BROWN, G. & YAALON, D. H. (1959). The origin and development of brown earths on Clay-with-flints and Coombe deposits. *J. Soil Sci.* **10**, 177-195.

Field investigation of the origin and development of three brown-earth (sol lessivé) profiles was supplemented by mechanical and mineralogical analyses and micromorphological studies. Two profiles, representative of the Batcombe and Winchester series, were on Clay-with-flints and the third, of the Charity series, on a Coombe deposit.

Particle-size distribution and petrographic data strongly suggest that all three soils are derived in part from loess. The Charity is interpreted as an autochthonous profile formed on Head of chalky and flinty detritus mixed with loess by solifluxion, whereas the Batcombe and Winchester are two-stage profiles, formed on composite (non-uniform) parent materials resulting from the superficial incorporation of loess with the truncated or redeposited remains of previously weathered horizons with rotlehm and/or braunlehm fabrics derived from Chalk and Eocene beds in varying proportions, weathered in Tertiary or interglacial periods and rearranged by peri-glacial agencies. Clay-with-flints *sensu stricto*, e.g., in the Winchester subsoil, has distinctive physical, mineralogical and micromorphological characteristics, and appears to have originated by sub-surface solution of the Chalk and illuvial accumulation of clay mainly derived from overlying deposits.

The land-surfaces concerned have probably been subjected to at least one alternation of periglacial and temperate conditions after the addition of loess. Hence the extent to which either profile reflects the influence of the contemporary environment is not readily assessed, but evidence is adduced that the upper horizons of each profile bear the impress of similar pedogenic processes, including eluviation of clay-size material and acidic weathering leading to the accumulation of vermiculite, modified in the Winchester by the effects of erosion and soil creep.

- 17.2. CRAMPTON, C. B. (1959). Analysis of heavy minerals in certain drift soils of Yorkshire. *Proc. Yorks. geol. Soc.* **32**, 69-82.

Comparison of the heavy mineral suites in drift soils over Trias, Permian and Carboniferous rocks near Leeds with those of the underlying rocks suggests that, apart from certain shallow sedimentary soils over Magnesian Limestone, much material in the remaining drift soils was derived from outside the out-crop of the underlying rock. Material from the Magnesian Limestone has been widely distributed in the area, suggesting a slight extension of the Vale of York glacier beyond the Linton-Sutton Kame Belt.

- 17.3. CRAMPTON, C. B. (1959). Heavy minerals in certain Old Red Sandstone and Silurian limestone of Monmouth. *Nature, Lond.* **183**, 485.

### Library

#### Book

- 18.1. BOALCH, D. H. (1960). *World directory of agricultural libraries and documentation centres*. Harpenden: International Association of Agricultural Librarians & Documentalists.