ROTHAMSTED RESEARCH

# Report for 1968 - Part 1

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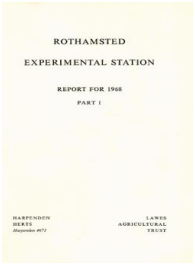


## Abstracts of Rothamsted Papers

### Rothamsted Research

Rothamsted Research (1969) *Abstracts of Rothamsted Papers ;* Report For 1968 - Part 1, pp 319 - 375 **- DOI: https://doi.org/10.23637/ERADOC-1-123**

# ABSTRACTS OF PAPERS



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## Physics Department

### General Papers

1.1 Brown, N. J. (1968) The influence of cultivations on cereal production. *Fmr Stk Breed*, 30 April 1968.

1.2 Penman, H. L. (1968) Weather, 1967. *Trans. Herts. nat. Hist. Soc.* **26**, 263–266.

### Research Papers

1.3 Brown, N. J. (1968) Herbicide/tillage systems in England. *Proc. 9th British Weed Control Conference, 1968*, **3**, 1297–1301.

Now that many weeds can be killed by herbicides, on freely-draining light soils economic yields of cereals and kale can be achieved without tillage. There are problems on other soils: unsatisfactory plant establishment on poorly draining heavy soils; damage to soil structure caused by harvesting and spraying traffic; and the unhindered increase of rhizomatous weeds.

Success on a farm scale can be expected from tillage techniques that lie between the traditional and none at all. Machinery designers have not yet started to exploit the possibility of herbicidal control of weeds.

1.4 Legg, B. J. & Parkinson, K. J. (1968) Calibration of infra-red gas analysers for use with carbon dioxide. *J. scient. Instrum.* (Series 2), **1**, 1003–1006.

An infra-red gas analyser, used for differential measurement of carbon dioxide concentrations, was calibrated by a pressure difference method and also by absolute concentration differences. The two calibrations differ, and a correction factor for the pressure method was obtained.

1.5 Parkinson, K. J. (1968) Apparatus for the simultaneous measurement of water vapour and carbon dioxide exchanges of single leaves. *J. exp. Bot.* **19**, 840–856.

Equipment is described that delivers air whose concentrations of carbon dioxide and water vapour are closely controlled in the ranges 0–2500 ppm and 5–15 mb respectively, at flow rates of up to 10 litres per minute, to each of four leaf chambers. The leaf temperature is controlled to $\pm 0{\cdot}5^\circ$ C and, with a light intensity of 0·3 cal $cm^{-2}$ $min^{-1}$ visible radiation (0·4–0·7 $\mu$), leaf temperature can be maintained at 17·5° C.

The apparatus used to measure the concentration differences between the water vapour and $CO_2$ entering and leaving the leaf chamber (used to calculate transpiration, photosynthetic and respiration rates) is described.

Results of tests, which show the necessity for mounting a fan within the leaf chamber, are reported.

Typical light and $CO_2$ response curves are given for kale leaves (*Brassica oleracea* var. acephala) and an attempt is made to quantify the errors in the measurement of photosynthesis and transpiration.

1.6 Penman, H. L. (1968) Climate and crops. (Ramsden Memorial Lecture.) *Mem. Proc. Manchr lit. phil. Soc.* **110**, 1–13.

Incoming radiation determines both the potential water use by crops, and the potential growth rate within a given system of management. Particular studies show the interactions of water supply and energy supply on grass at Rothamsted and at the Grassland Research Institute at Hurley, and on cotton in East Africa.



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A general survey of world efficiency in fixing solar energy in cereals indicates a gap, by a factor of about five, between average achievement in under-developed countries and that in developed countries.

1.7 PENMAN, H. L. (1968) The earth's potential. *Science Journal*, May, 43–47.

The general survey of 1.6 is extended to give detailed comparisons of rice with other cereals, as a clue to where lack of water can be identified as the main source of small crop yields. There are a few such countries, but in most lack of water is not the reason for inefficient farming.

1.8 ROSE, D. A. (1968) Water movement in porous materials: Part 3. Evaporation of water from soil. *Br. J. appl. Phys.* (Series 2), **1**, 1779–1791.

The equation of vertical flow is adapted to describe the evaporation of water from a semi-infinite porous material during the second stage of drying when water loss is limited by the distribution of water in the material. Flow measurements on long columns of aggregates of six soil materials confirm the theory, and enable the transport parameters controlling flow to be found over the range of volumetric water content $\theta$ ($cm^3$ water/$cm^3$) from aggregate saturation $\theta_c$ to dryness (i.e. from near pF 2 to near pF 7).

Evaporation from porous materials initially at a uniform water content $\theta_c$ produces profiles of $\theta$ invariant with $zt^{-1/2}$ (where $z$ is the depth in cm and $t$ the time in seconds) which differ for each material. As $\theta$ decreases from $\theta_c$, diffusivities ($D$ $cm^2$ $s^{-1}$) calculated from these profiles fall to a minimum, then rise to a subsidiary maximum close to dryness, before falling again as $\theta$ approaches zero. Such behaviour accords with prediction. Hydraulic conductivities ($k$ cm $s^{-1}$) fall continuously as $\theta$ decreases from $\theta_c$ to zero.

1.9 ROWSE, H. R. & MONTEITH, J. L. (1969) A fifty-channel digital recorder for thermocouple psychrometers. *J. scient. Instrum.* (Series 2), **2**. (In the press.)

Outputs from fifty thermocouples are recorded by converting the movement of a galvanometer light spot into a series of electrical impulses, which are then amplified, shaped, counted and finally printed on a paper strip. The thermocouples act as wet- and dry-bulb thermometers to measure the relative humidity of vapour in equilibrium with small samples of soil or plant material and the principle of Peltier cooling is exploited to deposit water on the wet-bulbs. Passage of the cooling current, switching of the thermocouple circuits and the initiation of counting and printing operations are controlled by a programme timer and a selector that allows any combination of psychrometer units to be scanned repetitively. The precision of the system (equivalent to one digit) is $\pm 0{\cdot}0007°$ C or 0·007% in relative humidity at 25° C or 10 J $kg^{-1}$ (1 metre) in water potential.

1.10 SZEICZ, G. (ENDRODI, G. & TAJCHMAN, S.) (1969) Aerodynamic and surface factors in evaporation. *Water Resources Res.* **4**, No. 2.

Measurements of $z_0$ and other aerodynamic qualities of three crops in Germany (pine forest, lucerne, potatoes) are combined with British records. The collection is coherent with American experience of Tanner and Pelton and permits the following generalisations. For pliable agricultural crops the roughness length decreases with increasing wind speed (to $\frac{1}{2}$ for 1–3 m $sec^{-1}$). For all these crops, in this range, $z_0 \simeq$ crop height/10. Calculations of eddy conductivity ($1/r_a$) give values three times that of open water for the farm crops, and thirty times for the trees. From measured values of components in the energy balance (net radiation



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$R$, soil heat flux $G$ and evaporation $\lambda E$) the surface resistances of the crops are calculated using an empirical relation given by Monteith. Values of $r_s$ for the trees—between 1·0 and 1·5 sec $cm^{-1}$—are always two to four times as great as for the farm crops, indicating very effective stomatal control of transpiration by pine leaves.

In southern England, the effect of including the two specific crop parameters $r_a$ and $r_s$ in Penman's combination formula for evaporation, is, on balance, negligible for fully grown farm crops.

Calculation for trees could agree well with Rutter's measurements, if some allowance is made for the extra rapid evaporation of intercepted water arising from the very small value of $r_a$.

To extend the testing range, calculations are repeated for the Californian climate. Using similar empirical estimates of $R$ and $G$ as in southern England (derived from measured values of incoming solar radiation) and specific values of $r_a$ and $r_s$ the calculated summer values of evaporation for open water, potatoes and lucerne agree (within 10–20%) with measured field values.

1.11 SZEICZ, G. & LONG, I. F. (1969) Surface resistance of crop canopies. *Water Resources Res.* **4**. (In the press.)

Three analytical and two empirical methods are described to calculate the surface resistance, $r_s$, of crops transpiring at a measured rate. The *profile* method is applicable when detailed temperature, humidity and wind profiles are measured; for the *residual* method, measurements of surface temperature, wind and humidity are enough; for the *heat balance* method, the calculation is based on the ratio of potential to actual evaporation. For rough estimates, an *empirical equation of Monteith*, or a *relation between leaf area and surface resistance*, can be used. In southern England and in California all three analytical methods agree closely. Hourly values of $r_s$ in California demonstrate the effect of water stress on an irrigated grass canopy by midday, whereas in England $r_s$ of a barley crop is maintained constant for almost the whole day. From Aslyng's measurements of evaporation, the relation of $r_s$ to soil water potential is calculated and used to show how relative rates of transpiration and photosynthesis may change in response to water stress. For an equatorial rain forest in Kenya, mean monthly $r_s$ varied systematically with soil moisture deficit, ranging between 0·3 and 1·1 sec $cm^{-1}$.

## Chemistry Department

### THESIS

2.1 SPRATT, E. D. (1968) Studies on the utilisation of fertiliser nitrogen by spring wheat. Ph.D. Thesis, University of London.

### GENERAL PAPERS

2.2 BENZIAN, B. (1968) Nutrition of young conifers and soil fumigation. *Abstr. Pap. 1st int. Congr. Pl. Path.* London, 1968, p. 13.

2.3 BENZIAN, B. (1967) Test on three nitrogen fertilisers—'Nitro-Chalk', formalised casein and isobutylidene diurea—applied to Sitka spruce (*Picea sitchensis*) seedlings in two English nurseries. *Colloquium on forest fertilisation.* (*Proceedings of Vth Colloquium of the International Potash Institute, Finland*), pp. 171–175.

2.4 BENZIAN, B. (1967) Manuring young conifers: experiments in some English nurseries. *Colloquium on forest fertilisation*, (*Proceedings of the Vth Colloquium of the International Potash Institute, Finland*), pp. 142–169.



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2.5 BENZIAN, B. & FREEMAN, S. C. R. (1968) Nutrition experiments in forest nurseries. Isobutylidene diurea (IBDU). *Rep. Forest Res., Lond.*, 1968, 140–142.

2.6 COOKE, G. W. (1968) Soils and fertilisers. *Jl R. agric. Soc.* **129**, 128–148.

2.7 COOKE, G. W. (1968) The forms and amounts of fertilisers used in U.K. and possible changes that may affect methods of application. *J. Proc. Instn agric. Engrs* **23** (No. 3), 142–148.

2.8 COOKE, G. W. (1968) Future trends in the use of fertilisers. *Proc. Fertil. Ass. Ire.* No. 1, pp. 1–25.

2.9 COOKE, G. W. (1968) Manures and fertilisers. Contribution to: *The agricultural notebook*, originally compiled by Primrose McConnell. 15th edn. London: Iliffe Books Ltd., pp. 101–133.

2.10 GASSER, J. K. R. (1968) The effects of soil management on available nitrogen. *Stikstof* (Dutch Nitrogenous Fertiliser Review) No. 12, pp. 132–143.

2.11 TALIBUDEEN, O. (1966) Potassium in soils and clays. *Rep. Prog. appl. Chem.* **51**, 287–291.

## RESEARCH PAPERS

2.12 BOLTON, J. & PENNY, A. (1968) The effects of potassium and magnesium fertilisers on yield and composition of successive crops of ryegrass, clover, sugar beet, potatoes, kale and barley on sandy soil at Woburn. *J. agric. Sci., Camb.* **70**, 303–311.

Potassium sulphate and, to a lesser extent, magnesium sulphate increased yields of all crops when applied separately or together. Although K/Mg interactions did not affect yields, they considerably affected the ratio of concentrations of these elements in the dry matter of the crops. Sodium chloride increased yields of kale but not of barley cut green when coming into ear.

Percentage yield response to potassium were in the order: potatoes (218%) > clover = barley > sugar beet > kale > ryegrass (17%). Magnesium increased yields from 3 to 10%, most with potatoes.

Changes in exchangeable magnesium in the soil reflected differences between amounts given and amounts taken up by the crops. Non-exchangeable potassium was released on plots where potassium was not given and 'fixed' in non-exchangeable forms where it was.

Magnesium deficiency symptoms have become more common recently in South-east England, probably because the local liming materials contain only small amounts of magnesium and less FYM is used than previously.

2.13 CORNFORTH, I. S. (1968) The effect of the size of soil aggregates on nutrient supply. *J. agric. Sci., Camb.* **70**, 83–85.

Soil aggregates of different sizes, separated by sieving, and artificial aggregates stabilised by a chemical conditioner were used to study how particle size affects the uptake of nitrogen and phosphorus by plants growing in pots. Less phosphate was consistently taken up from the coarser than from the finer fractions of soil; also less nitrate despite its ability to move in soil moisture.



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2.14 CORNFORTH, I. S. (1968) Relationships between soil volume used by roots and nutrient accessibility. *J. Soil Sci.* **19**, 291–301.

Increasing the volume of soil provided for plants growing in pots increased yields of oats, ryegrass, kale and tomatoes, and decreased the intensity of rooting; it increased the supply of N more than of P, because P uptake was correlated with root intensity and N uptake was not. Responses to P fertiliser were greater, and to N smaller, in the larger volumes than in the smaller volumes of soil. Isoquants showed that, when soil volume is restricted, it is more important to apply a mobile nutrient (nitrate) than an immobile nutrient (phosphate), although the value of either nutrient in compensating for too little soil depends on the supply of the other.

2.15 COULTER, B. S. & TALIBUDEEN, O. (1968) Calcium: aluminium exchange equilibria in clay minerals and acid soils. *J. Soil Sci.* **19**, 237–250.

Exchange reactions between 0·01*N* $AlCl_3$ solutions of different pH and Ca-saturated montmorillonite, vermiculite, illite, and soils from the Park Grass Experiment at Rothamsted and the Deerpark Experiment at Wexford (Ireland), showed that $Al^{3+}$ and $Al(OH)_2^+$ were adsorbed from solutions of pH >4·0 and $Al^{3+}$ and $H^+$ from solutions of pH <3·0. When Al was adsorbed, the cation exchange capacity of Ca-saturated soils and clays increased.

Conventional Ca:Al exchange isotherms showed that $Al^{3+}$ was strongly preferred to $Ca^{2+}$ on all soils and clays. The equilibrium constant for Ca:Al exchange, K′, was identical for soils before and after oxidising their organic matter and did not vary, for any exchanger, with Al-saturation or the initial pH of the $AlCl_3$ solution. This proved the validity of the procedure used to calculate exchangeable $Al^{3+}$.

K′ values for Ca:Al exchange favoured $Al^{3+}$ in the order: vermiculite > Park Grass soil > Deerpark soil > illite > montmorillonite.

The influence of surface-charge densities of the clay minerals on this order was discussed and a method proposed and tested for calculating the K′ value of a soil from its mineralogical composition.

2.16 CUNNINGHAM, R. K. (1968) Cation–anion relationships in crop nutrition. VI. The effects of part, age and species of plant and some soil characteristics. *J. agric. Sci., Camb.* **70**, 237–244.

The effects of part, age and species of plant, and of some soil characteristics on the relationships between (*a*) *sum of the cations* (Σ cations)–% *total N* and (*b*) ratio of *sum of the cations:sum of the anions* (R)–% *organic N* relationships in crops were tested in four experiments in the glasshouse. Crops were grown in soil and given four or five amounts of $NO_3$–N and sometimes a uniform dressing of other nutrients.

There was a positive linear relationship between Σ cations in plants and their % total N when $NO_3$–N was supplied; the proportions of cations and anions entering roots from the soil solution (R values) varied and were in some way related to the elaborated nitrogen status of the plant, suggesting they may be linked with nitrogen metabolism. The cation–anion relationships were of the same general type regardless of the part of the plant that was analysed, its age or species, or of the type of soil in which it was grown. Analysis of leaves adequately reflects relationships in whole plants. Although the relationships had the same form with all species, dicotyledons had greater Σ cations and R values than monocotyledons at equal % total N and organic N respectively. Within the group of relationship curves obtained with different soils, at equal % total and organic N, Σ cations and R values were greater in grass grown in alkaline than in acid soil. Soil properties that affect the proportions of $NH_4$–N and $NO_3$–N



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presented to plant roots probably have an important influence on the relationships. These cation–anion relationships in crops were not changed when yields changed greatly.

2.17 GASSER, J. K. R. (1968) Mineralisable-N in the soil under various leys and its effect on the yields of following wheat. *J. agric. Sci., Camb.* **70**, 323–329.

Soil samples taken in the autumn after ploughing ryegrass, clover and ryegrass/clover leys were used to measure the mineral-N (ammonium-N + nitrate-N) in the fresh soil (mineral-$N_{fresh}$), the increase in mineral-N on incubating the fresh soils ($\Delta$ mineral-$N_{fresh}$) and the increase in mineral-N on incubating the re-wetted air-dry soils ($\Delta$ mineral-$N_{air-dry}$). Mineral-$N_{fresh}$ and $\Delta$ mineral-$N_{air-dry}$ were measured on further soil samples taken the following spring. Values of $\Delta$ mineral-$N_{air-dry}$ not only correlated best with grain yields and N uptakes by wheat without fertiliser-N, but also with yield responses and fertiliser-N recovered from fertiliser-N applied to the winter wheat.

Fertiliser-N applied to the ley altered measurements on samples taken in the autumn but not those taken the following spring.

Soil samples taken in the autumn 1960 from under three-year grass leys were used to measure mineral-$N_{fresh}$, $\Delta$ mineral-$N_{fresh}$ and $\Delta$ mineral-$N_{air-dry}$. Spring wheat was grown in 1961 followed by spring barley in 1962. Further soil samples were taken in spring 1962 after cultivations were complete and before the barley was sown or fertilisers applied.

$\Delta$ mineral-$N_{air-dry}$ was the best measurement to use on soils from under grass leys. Values depended on grass species, and were increased by N applied to the ley. Differences had largely disappeared 18 months later. $\Delta$ mineral-$N_{air-dry}$ was positively correlated with grain yields of spring wheat grown both with and without fertiliser-N, and with the yield response to, or the nitrogen recovered from, a dressing of 56 lb N/acre.

With fertiliser-N yields of winter wheat after the mixed leys tended to the same maximum value independently of mineralisable-N in the soil. After grass leys, maximum yields of spring wheat given fertiliser-N increased with increasing mineralisable-N in the soil.

2.18 GASSER, J. K. R. & HAMLYN, F. G. (1968) The effects on winter wheat of ammonium sulphate, with and without a nitrification inhibitor, and of calcium nitrate. *J. agric. Sci., Camb.* **71**, 243–249.

Winter wheat grown on a sandy loam and a clay loam was given ammonium sulphate alone or treated with the nitrification inhibitor, 2-chloro-6-(trichloromethyl)-pyridine, drilled with the seed, in autumn. In spring, dressings of treated or untreated ammonium sulphate or of calcium nitrate were broadcast. Seventy-five or 150 lb N/acre were given on the sandy loam and 50 or 100 lb on the clay loam.

Without fertiliser-N, the wheat yielded 17 cwt/acre on the sandy loam and 46 cwt on the clay, and with the double dressings given in spring yields were 52 and 56 cwt/acre. On the light soil, treated ammonium sulphate given in autumn increased yield by 3·5 cwt/acre with the single dressing and by 5·4 cwt/acre with the double one.

On the heavy soil the inhibitor had no effect on yield. Dressings of 50 lb N/acre in autumn or spring increased yields equally, but with 100 lb N/acre the spring dressing increased yield slightly more than autumn dressings. Calcium nitrate at 75 lb N/acre was significantly better than ammonium sulphate on the light soil.



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The inhibitor did not affect the speed with which N was taken up, or the total uptake, from fertiliser given in spring.

2.19 GASSER, J. K. R. & MITCHELL, J. D. D. (1968) The effects of previous cropping and fertiliser-N applied in field experiments on soil-N available to ryegrass grown in pots. *Trans. 9th int. Congr. Soil Sci., Adelaide* **2**, 449–458.

Soils taken in two successive Novembers from field experiments where grass, wheat and kale had been grown, were incubated out of doors during the winter and then used to grow ryegrass in the glasshouse. Little or none of the fertiliser-N applied in March for the field crops remained in the surface soil in November.

Each year ryegrass grown in pots in the glasshouse yielded less dry matter and contained less N when grown in soil taken from land under grass than from under wheat and kale. Yields of ryegrass and the amount of N taken up in the glasshouse during 1966 were increased by fertiliser-N given to all three crops in 1965, but during 1967 only by fertiliser applied for wheat and kale in 1966. With nitrogen added in the glasshouse, ryegrass recovered less from soil that had previously grown grass than from soils that had grown either wheat or kale.

It is concluded that yields were smaller after grass than after wheat or kale because, when ploughed, the soil under grass mineralised less N than under kale or wheat stubbles. Ryegrass grown in this soil also responded less to fertiliser-N.

2.20 HOYT, P. B. (1968) The effect of soil conditioners on the growth of sugar beet in a sandy loam soil. *Expl Husb.* No. 16, 70–72.

'Krilium' and farmyard manure (FYM) significantly increased yields of sugar beet grown on a calcareous sandy soil well supplied with nutrients and water. As percentages of nutrients in the crop were not consistently increased by the soil conditioners tested, their effect was probably on soil structure rather than directly on nutrient uptake. Unfavourable physical conditions in such light soils may be one reason for sugar beet growing badly.

2.21 MATTINGLY, G. E. G. & PENNY, A. (1968) Evaluation of phosphate fertilisers. I. Immediate value of dicalcium phosphate, nitrophosphates, Gafsa rock phosphate, basic slag and potassium metaphosphate for barley and ryegrass. *J. agric. Sci., Camb.* **70**, 131–138.

Three granular nitrophosphates containing 5, 26 and 50% of their total phosphorus in a water-soluble form, granular potassium metaphosphate, Gafsa rock phosphate and basic slag (both as powders) were compared with granular superphosphate and powdered dicalcium phosphate as standards in two experiments with ryegrass and three with barley.

In 1960 total yields of ryegrass during a whole season were similar with all fertilisers. Nitrophosphate-5, Gafsa rock phosphate and basic slag acted more slowly than granular superphosphate and grass grew less well and took up less phosphorus during the first 12 weeks. Over the whole growing season more phosphorus was taken up by grass from powdered dicalcium phosphate and from granular potassium metaphosphate (0·5–2·0 mm) than from granular superphosphate (1·0–4·0 mm).

Powdered dicalcium phosphate was equivalent to about 60% as much phosphorus applied as superphosphate to barley. Rock phosphate was almost inert and percentage granular superphosphate equivalents of basic slag and potassium metaphosphate were 22 and 23% respectively. Percentage superphosphate equivalents of the granular nitrophosphates were 1, 25 and 53% and almost equal to the water-soluble phosphate they contained.



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2.22 MATTINGLY, G. E. G. (1968) Evaluation of phosphate fertilisers. II. Residual value of nitrophosphates, Gafsa rock phosphate, basic slag and potassium metaphosphate for potatoes, barley and swedes grown in rotation, with special reference to changes in soil phosphorus status. *J. agric. Sci., Camb.* **70**, 139–156.

The residual value of three nitrophosphates, potassium metaphosphate, basic slag and rock phosphate was compared with that of superphosphate in two experiments with potatoes, barley and swedes grown in rotation. The residual value of the fertilisers was also compared with that of (*a*) six cumulative annual dressings of superphosphate supplying either one-half or the same total amounts of phosphate; (*b*) single dressings of superphosphate applied once in each rotation. Yields and phosphorus uptakes are discussed in relation to the amounts of soil phosphate soluble in 0·5*M* $NaHCO_3$.

In the first rotation residues of rock phosphate produced about 1 ton/acre less potato tubers than residues of other fertilisers and cumulative annual applications of superphosphate produced 0·6–0·9 tons/acre less tubers than all residues except rock phosphate. In the second rotation residues of fertilisers increased tuber yields less than cumulative dressings of superphosphate. Over two rotations mean yields from residues and from cumulative dressings were the same. Mean yields of barley over two rotations were 1–3 cwt/acre greater from residues than from cumulative annual dressings; the residual value of the different phosphates was the same. For swedes, residues from the alternative phosphates, including basic slag and rock phosphate, were equivalent to those from superphosphate and gave the same mean yields as six cumulative dressings of superphosphate broadcast at planting.

Average residual values of alternative phosphate fertilisers, calculated from (*a*) yield response; (*b*) P uptake; (*c*) soil analysis were: superphosphate, 100; nitrophosphates, 100–102; potassium metaphosphate, 95; basic slag, 94; Gafsa rock phosphate, 92. Mean percentage 'fresh' superphosphate equivalents of residues from all fertilisers were 17 and 26% after the first rotation and 11 and 15% after the second rotation for potatoes and swedes respectively.

The percentage of the total variance in crop yields accounted for by linear regression on $NaHCO_3$–soluble P ranged from 38 to 70% for potatoes, 9 to 28% for barley grain and 42 to 92% for swedes. Mean yields of the crops increased by 0·24 ± 0·037 tons/acre (potatoes), 0·22 ± 0·08 cwt/acre (barley) and 1·16 ± 0·148 tons/acre (swedes) for each ppm $NaHCO_3$–soluble phosphorus in the soil at harvest.

2.23 NOWAKOWSKI, T. Z. (1968) The effect of a nitrification inhibitor on the concentration of nitrate in grass during growth. *Pl. Soil* **28**, 165–168.

In an experiment on clay-loam soil, ammonium sulphate with or without the nitrification inhibitor 2-chloro-6-(trichloromethyl)-pyridine (at 2% of the weight of N in fertiliser) or sodium nitrate were applied at 100 or 200 lb N/acre to the seedbed before sowing S22 Italian ryegrass and again after the first cut. Eighty-four days after the first dressing, all the grass given 100 lb N/acre contained similar amounts of nitrate-N; with 200 lb N/acre, grass given ammonium sulphate alone contained most nitrate-N and grass given ammonium sulphate plus inhibitor least. Forty-two days after the second dressing, all the grass given 100 lb N/acre again contained similar amounts of nitrate-N and, with 200 lb N/acre, grass given sodium nitrate contained most nitrate-N and that given ammonium sulphate plus inhibitor least.

2.24 SALT, P. D. (1968) The automatic determination of phosphorus in extracts of soils made with 0·5*M* sodium hydrogen carbonate and 0·01*M* calcium chloride. *Chemy Ind.* 584–586.

Two procedures are described for determining inorganic phosphorus in 0·5*M*



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$NaHCO_3$ and 0·01*M* $CaCl_2$ extracts of soils using the Technicon AutoAnalyzer. With 0·01*M* $CaCl_2$ extracts containing small amounts of inorganic phosphorus, the procedure requiring heat to develop colour gave significantly larger values than the procedure at room temperature, because organic phosphates present were hydrolysed.

2.25 TALIBUDEEN, O. & DEY, S. K. (1968) Potassium reserves in British soils. I. The Rothamsted Classical Experiments. *J. agric. Sci., Camb.* **71**, 95–104.

Thirty-four soils from the Rothamsted Experiments were exhaustively cropped with ryegrass in the glasshouse. The concentration and yield of potassium in ryegrass tops and the potassium intensity in the soil were measured every 4 weeks, after harvesting the grass.

The change in K-intensity of soils, rich in potassium, with exhaustion differed from that of 'poor' soils. This change was related to the rate of change of the cumulative K-yield. The rate of change of soil K-intensity demarcated periods of intense and limited exhaustion, and partial recovery, of the soil during cropping.

The cumulative K-yield of ryegrass was significantly related to the K-intensity of the uncropped soil; the '16-week' yield was slightly better related than the '60-week' yield. For Park Grass soils, the relationship was improved by allowing for variations in soil pH.

The K-intensity of all soils, with or without manuring, decreased to nearly $10^{-3}$ $(M)^{\frac{1}{2}}$ in $(AR)_0$ units after 16 weeks cropping, although large differences in K-yield persisted much longer.

K-buffer capacity *per unit clay content* of the soil, measured by a laboratory method, was inversely related to the K-intensity of the uncropped soil. The K-buffer capacities of soils rich in potassium, measured in laboratory and glasshouse experiments, were significantly related, but were unrelated for 'poor' soils. The K-buffer capacity (laboratory method) of Rothamsted soils with different manurial treatments was only very approximately related to the cumulative K-yield.

Less K was taken up from all Rothamsted soils given nitrogen fertiliser in the field, and their K-intensities were smaller, than the corresponding soils without N. Field liming of acid soils decreased their K-intensity and increased their K-buffer capacity, presumably because more potassium was removed by the field crops.

A rapid method is suggested for measuring potassium intensities of soils.

2.26 TALIBUDEEN, O. & DEY, S. K. (1968) Potassium reserves in British soils. II. Soils from different parent materials. *J. agric. Sci., Camb.* **71**, 405–411.

Twenty-six soils from different parent materials were exhaustively cropped with ryegrass in the glasshouse. Soil and crop measurements revealed inter-relationships generally similar to those observed with Rothamsted soils (Part I), except that 12 of 20 soils 'poor' in K (as defined by the K-intensity with cropping) gave patterns of K-uptake by the ryegrass crop resembling those of soils 'rich' in K. This indicates that these soils contain some potassium reserves not differentiated by laboratory measurements from those accumulated by K-manuring in Rothamsted soils.

The cumulative K-yield of ryegrass was significantly related to the K-intensity of the uncropped soil. The relationships were improved slightly by allowing for differences in soil pH and organic carbon content. The cumulative K-yields at 16 weeks and at 60 weeks were better related to the total clay ($<2\ \mu$) content than to the fine clay ($<0{\cdot}2\ \mu$) content of the soil. The K-intensities of the cropped soils decreased to nearly $10^{-3}$ (AR) units after 16 weeks cropping (except the Harwell



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soil which took 3 years to do so) although large differences in K-yield persisted much longer.

K-buffer capacity per unit clay content of the soil (by a laboratory method) was inversely related to the K-intensity of the uncropped soil and to K-uptakes at 16 and 60 weeks. The reasons for this apparent anomaly are discussed and a more correct basis suggested for the units for potassium buffering capacity. The buffer capacities of 'rich' but not 'poor' soils were significantly related in the laboratory and glasshouse experiments.

After a drying-and-wetting cycle, soils exhausted by cropping released more potassium to ryegrass, in amounts proportional to the clay content of the soil. This points to the need for caution in measurements to assess potassium status after air-drying soils.

2.27 VAIDYANATHAN, L. V. & TALIBUDEEN, O. (1968) Rate-controlling processes in the release of soil phosphate. *J. Soil. Sci.* **19**, 342–353.

The isotopic exchange of phosphate ions in a deep river gravel soil, maintained at different pHs from 3·5 to 6·7 in a field experiment, established by the N.A.A.S. at Shardlow, was governed initially (<20 h) by simultaneous 'first-order' and 'bulk-diffusion' kinetics, but later by 'bulk-diffusion' kinetics only. The 'bulk-' or 'intracrumb-diffusion' coefficient was independent of phosphate manuring, was least at pH 5·5 and increased on either side of this critical pH. The rate constant for the phosphate component exchanging initially with 'first-order' kinetics increased significantly with phosphate manuring at pH 3·5, 4·4 and 5·5, although the constants for unmanured and manured soils did not change with soil pH. But at pH 6·7, the rate constants for the unmanured and phosphate-treated soils exceeded those in the more acid soils, although the constant for the manured soil was just significantly greater than that of the unmanured soil.

Residual phosphate (i.e. the difference between manured and unmanured soils) adsorbed on the soil was greater in the more acid soils, where water-soluble residual phosphate increased with soil pH to a maximum at pH 5·5. Residual phosphate, exchanging initially, decreased to nothing above pH 6·5.

2.28 WIDDOWSON, F. V. & PENNY, A. (1968) Results of an experiment at Rothamsted testing farmyard manure and N, P and K fertilisers on five arable crops and permanent grass. III. Yields 1961–1965. *J. agric. Sci., Camb.* **70**, 53–58.

In an experiment begun in 1956, using a five-course rotation of barley, grass-clover ley, potatoes, wheat and kale and a block of permanent grass, N decreased yields of the rotation ley, slightly increased yields of potatoes (after the ley), but greatly increased yields of wheat, barley and kale and permanent grass. P increased the yields of all arable crops, of kale dramatically, but not of permanent grass. K, which greatly increased yields of wheat, the rotation ley, and even more, of potatoes, only slightly increased yields of barley, kale and permanent grass.

FYM increased the yields of all crops; potatoes most. Applying fertilisers with the FYM diminished its effects, but largest yields of all except wheat and barley were obtained by combining the two.

Mean yields from all combinations of N, P and K were a little smaller between 1961 and 1965 than between 1956 and 1960, and the yields were maintained best by applying FYM and fertilisers together. Responses to N and to K were similar in both rotations, but responses to P became larger with time.

2.29 WILLIAMS, J. D. H. (1968) Adsorption and desorption of simazine by some Rothamsted soils. *Weed Res.* **8**, 327–335.

The adsorption of simazine from, and subsequent desorption into, 0·01*M*



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calcium chloride solution was studied in 23 Rothamsted soils taken from sites with different cropping histories and manurial treatments. Organic carbon content was the only factor related to ability of soil to sorb simazine; this accounted for 90% or more of the variation between soils. Time to attain equilibrium during adsorption ranged from fewer than 2 to more than 24 hours. Equilibrium during desorption was only occasionally attained within 24 hours. Differences between theoretically predicted and measured concentrations of simazine in solution after desorption were least for soils that soonest attained equilibrium during adsorption. Differences in adsorption and desorption kinetics between the soils used could not be related to soil pH, organic carbon content, cropping or manuring history. Comparisons of unlimed and limed soils suggested simazine was not lost by acid hydrolysis during the experiments.

2.30 WILLIAMS, R. J. B. & LE RICHE, H. H. (1968) The effect of traces of beryllium on the growth of kale, grass and mustard. *Pl. Soil* **29**, 317–326.

Kale, grass and mustard were grown in soil and in nutrient solution containing various concentrations of beryllium. One to two ppm of dissolved Be was toxic to plants grown in nutrient solution or in acid soils but not in soil containing free calcium carbonate. A soluble beryllium salt significantly increased growth of crops in a calcareous soil but was persistently toxic to them in an acid sandy loam.

## Pedology Department

### RESEARCH PAPERS

3.1 BLOOMFIELD, C., COULTER, J. K. & KANARIS-SOTIRIOU, R. (1968) Oil palms on acid sulphate soils in Malaya. *Trop. Agric.* **45**, 289–300.

Scattered throughout the coastal alluvial soils of Malaya, patches of soils with large reserves of sulphides are as acid as pH 2·5, when drainage allows the pyrites to oxidise quickly. Intensive drainage increases the acidity, which does not decrease after five or six years of leaching. Even after such intensive leaching the reserves of oxidisable sulphur remain very large. The growth of oil palms is severely restricted, and their yields small, in drained soils more acid than about pH 3·8 and containing water-soluble sulphate in the top 30 in. The yield and growth can be improved by raising the water table to keep the sulphide-bearing horizons in an unoxidised state. Liming, because of its cost and the difficulty of moving the lime into the deeper horizons, is not an economic method of reclamation.

3.2 BROWN, G. & (GASTUCHE, M. C.) (1967) Mixed magnesium–aluminium hydroxides. II. Structure and structural chemistry of synthetic hydroxycarbonates and related minerals and compounds. *Clay Min.* **7**, 193–201.

A structural scheme is proposed for the synthetic Mg–Al hydroxycarbonates described in Part I (Gastuche, Brown and Mortland, 1967) based on chemical and X-ray powder data. The structure consists of positively-charged brucite-like layers in which Al replaces Mg up to a maximum of about one in three sites. The positive charge is balanced by an interlayer sheet containing carbonate groups and water molecules. The idealised structural formula for the Al-rich material is:

$$[Mg_4Al_2(OH)_{12}]^{2+}[CO_3 3H_2O]^{2-}$$

A similar structural scheme seems to apply to many other materials including the minerals of the pyroaurite group, the compound $4CaO.Al_2O_3.13H_2O$ and the related mineral hydrocalumite, a nickeliferous magnesium hydroxide mineral



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described recently, and to many synthetic products that have been referred to as double sheet structures.

3.3 GAD, M. A., CATT, J. A. & LE RICHE, H. H. (1969) Geochemistry of the Whitbian (Upper Lias) sediments of the Yorkshire coast. *Proc. Yorks. geol. Soc.* **37**, 105–139.

The Whitbian sediments exposed on the Yorkshire coast consist of grey pyritic shales with bands of calcareous and sideritic concretions and, are divided in upward succession, into: the Grey Shales, the Jet Rock Series, the Alum Shale Series and the Peak Shales. Two slightly different successions are separated by a transcurrent fault (the Peak Fault).

The paper describes the mineralogical composition and major and minor element geochemistry of detrital and non-detrital constituents of sediments from all parts of the Whitbian succession except the Peak Shales. The detritus was severely weathered and was probably derived mainly from Palaeozoic clastic sediments. The abundance of organic matter, especially in the Jet Rock Series, indicates anaerobic conditions of deposition, and it is suggested that precipitation of calcium carbonate depended partly on the reducing conditions. Post-depositional changes involving both detrital and non-detrital components of the sediments are discussed, and two main diagenetic phases are recognised. In the earlier phase some of the calcareous nodules developed and pyrites was formed by bacterial sulphate reduction. The later phase was characterised by development of sideritic nodules, though some calcareous concretions also formed. The origin of jet in the Jet Rock Series is discussed. Geochemical correlations of beds on either side of the Peak Fault supports correlations based on lithological and palaeontological similarities.

3.4 (GASTUCHE, M. C.), BROWN, G. & (MORTLAND, M. M.) (1967) Mixed magnesium–aluminium hydroxides. I. Preparation and characterisation of compounds formed in dialysed systems. *Clay Min.* **7**, 177–192.

The minerals formed by dialysis of the precipitates formed by reaction of NaOH with Mg–Al solutions are described. In addition to aluminium and magnesium hydroxides, two hydroxycarbonates having Mg/Al ratios of about 5:1 and 2:1 are formed, essentially pure, from solutions with Mg/Mg + Al molar ratios of 0·8 and 0·7 respectively. X-ray powder data shows that they have partially ordered hexagonal layer structures with unit layer dimensions $a = 3{\cdot}048$ Å, layer thickness 7·60 Å for the Al-rich compound and $a = 3{\cdot}072$ Å, layer thickness 7·92 Å for the Al-poor compound. X-ray and chemical data show that the compounds resemble the minerals hydrotalcite and manasseite and also the compounds described as Mg–Al hydroxides by Feitknecht.

3.5 JENKINSON, D. S. (1968) A titrimetric method for determining total sulphur in mineral soils. *Analyst, Lond.* **93**, 535–539.

A rapid method is described for determining total sulphur in mineral soils. The various sulphur compounds in soil are first oxidised to sulphate by a mixture of potassium dichromate and phosphoric acid, and the sulphate thus formed is then reduced to sulphur dioxide by heating with activated charcoal. The evolved sulphur dioxide is trapped in hydrogen peroxide, barium perchlorate added to the resulting sulphuric acid to precipitate barium sulphate, and the excess barium determined by titration against standard potassium sulphate, with sulphonazo III as indicator. The proposed method gave acceptable results when tested on pure compounds and on soils of known sulphur content. No interferences are to be expected from normal soil constituents.



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3.6 KING, H. G. C. & PRUDEN, G. (1968) The purification of commercial Alizarin Red S for the determination of aluminium in silicate minerals. *Analyst, Lond.* **93**, 601–605.

Sephadex G-10 was used to isolate sodium alizarin sulphonate from commercial samples of Alizarin Red S that contained variable and large amounts of inorganic salts. Aluminium in silicate minerals can be reliably determined with the purified reagent, which gives a linear response up to 180 μg of aluminium per 100 ml.

3.7 LE RICHE, H. H. (1968) Metal contamination of soil in the Woburn market-garden experiment resulting from the application of sewage sludge. *J. agric. Sci., Camb.* **71**, 205–208.

Figures are quoted for metal content of sewage sludge, of soil treated with it and of plants grown on treated and untreated soil.

3.8 LE RICHE, H. H. (1968) Ion-exchange concentration of trace elements for spectrochemical analysis of rocks and soils. *Geochim. cosmochim. Acta*, **32**, 791–794.

Samples are dissolved in HF, $H_2SO_4$, HCl and $HNO_3$ and the chloro-complexes collected on an anion-exchange resin to concentrate Ag, Mo, Pb, Sn and Zn. The resin is dry-ashed and analysed by d.c. arc. The limits of detection are: Ag, 0·02; Mo, 0·1; Pb and Sn, 0·5; Zn, 20 ppm.

3·9 NEWMAN, A. C. D. (1968) A simple apparatus for separating fluorine from aluminosilicates by pyrohydrolysis. *Analyst, Lond.* **93**, 827–831.

Fluorine-bearing minerals are hydrolysed at 700–800° C in a gas-heated silica tube. The hydrogen fluoride evolved is absorbed in alkali and determined by titration with thorium nitrate or absorptiometrically with cerium alizarin complexone. Recoveries from sodium fluoride averaged 98·6% with a coefficient of variation of 3·2%, and the determined fluorine contents of the silicate rock standards GSP-1 and G2 were 0·381% and 0·134%. The method is simple and quick, and is suitable for determining fluorine in micas and related aluminosilicates.

3.10 PRUDEN, G. & BLOOMFIELD, C. (1968) The determination of ferrous sulphide in soil in the presence of ferric oxide. *Analyst Lond.* **93**, 532–534.

Hydrogen sulphide is partially oxidised by $Fe^{3+}$ when soils containing sulphide and ferric oxide are acidified. Satisfactory recoveries of hydrogen sulphide are obtained by using a solution of stannous chloride in hydrochloric acid to decompose the sulphide.

3.11 ROBERSON, H. E., WEIR, A. H. & WOODS, R. D. (1968) Morphology of particles in size-fractionated Na-montmorillonites. *Clays Clay Miner* **16**, 239–247.

Electron microscopy of particles in size fractions (0·5–1·0 μ, 0·1–0·5 μ, 0·05–0·1 μ and <0·05 μ esd) obtained by centrifugation of Na-saturated montmorillonites from Wyoming (two samples), Chambers, Arizona and Fayette County, Texas, showed details of particle morphology. The finest fraction of each montmorillonite consists predominantly of very thin separate flakes whereas all coarser fractions, totalling 80% or more by weight of the samples studied, are composed of microaggregates. For all the samples, preferred orientation is best developed in specimens formed from flakes of the finest fractions. Microaggregates are stable in dilute suspension, although they swell to give large interlayer spacings; they can be disrupted into smaller, thinner flakes by ultrasonic vibration. Differences in the dispersion behaviour of separate flakes and microaggregates



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are not due to differences in interlayer charge or chemical composition, which are very small between fractions of each sample, but are thought to depend on the interlocking of flakes in microaggregates during crystal growth, which prevents their complete separation in dilute suspension.

3.12 WHEELER, A. W. & KING, H. G. C. (1968) Conversion of tryptophan to auxin by phenolic esters from leaves of dwarf French bean (*Phaseolus vulgaris* L.). *Phytochemistry* **7**, 1057–1063.
(For summary see No. 5.17.)

3.13 WILLIAMS, R. J. B. & LE RICHE, H. H. (1968) The effect of traces of beryllium on the growth of kale, grass and mustard. *Pl. Soil* **29**, 317–326.
(For summary see No. 2.30.)

## Soil Microbiology Department

### GENERAL PAPERS

4.1 NUTMAN, P. S. (1969) Genetics of symbiosis and nitrogen fixation in legumes. *Proc. R. Soc. B.* (In the press.)

### RESEARCH PAPERS

4.2 BROWN, M. E. & the late SUSAN K. BURLINGHAM (1968) Production of plant growth substances by *Azotobacter chroococcum*. *J. gen. Microbiol.* **53**, 135–144.

Cultures of *Azotobacter chroococcum* strain A6 grown for 14 days contained gibberellin-like substances in the supernatant fraction. These substances were detected by pea and lettuce bioassay and when applied to roots of tomato seedlings also altered the later growth of stems, leaves and flowers. Azotobacter cultures contained three gibberellins; the main one has an $R_F$ value similar to that of GA3, and the others were not identified.

4.3 DART, P. J. (1968) Localisation of peroxidase activity in legume root nodules. *Electron microscopy, 1968. Pre-Congress Abstracts of Papers presented at the Fourth European Regional Conference held in Rome.* Vol. II, 69–70.

Localisation of peroxidase activity in thin sections of soyabean suggests that leghaemoglobin occurs outside the membrane envelopes that enclose the bacteroids.

4.4 (SORIANO, S.) & WALKER, N. (1968) Isolation of ammonia-oxidising autotrophic bacteria. *J. appl. Bact.* **31**, 493–497.

Procedures are described for isolating ammonia-oxidising autotrophic bacteria in pure culture, using solid media made from purified agar and appropriate micromanipulations.

## Botany Department

### GENERAL PAPERS

5.1 HUMPHRIES, E. C. (1969) The beneficial effect of CCC on wheat yields in dry conditions. *Euphytica* **17**, Suppl. 1, 275–279.



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5.2 HUMPHRIES, E. C. (1968) Responses of crop plants to growth regulators. *S.C.I. Monogr.* No. 31 (Symposium held on 8–9 January 1968), pp. 251–258.

5.3 HUMPHRIES, E. C. (1969) Influence of CCC on root growth of cereals. In: *Root growth.* (Proceedings of the 15th University of Nottingham Easter School in Agricultural Science.) London: Butterworth, p.392.

5.4 HUMPHRIES, E. C. (1968) CCC and cereals. *Fld Crop Abstr.* **21**, 91–99.

5.5 THURSTON, J. M. (1968) Focus on blackgrass. *Fmr Stk Breed.* **82**, No. 4085, 71–72.

5.6 THURSTON, J. M. (1969) The effect of liming and fertilisers on the botanical composition of permanent grassland, and on the yield of hay. In: *Ecological aspects of the mineral nutrition of plants.* (British Ecological Society Symposium, 1968.) Oxford: Blackwell Scientific Publications, pp. 3–10.

5.7 THURSTON, J. M. & WILLIAMS, E. D. (1969) Growth of perennial grass weeds in relation to the cereal crop. *Proc. 9th British Weed Control Conference, 1968*, **3**, 1115–1123.

5.8 WATSON, D. J. (1968) A prospect of crop physiology. *Ann. appl. Biol.* **62**, 1–9.

5.9 WELBANK, P. J. (1969) Equipment for sampling roots of field crops. In: *Root growth.* (Proceedings of the 15th University of Nottingham Easter School in Agricultural Science.) London: Butterworth, pp. 411–412.

## RESEARCH PAPERS

5.10 GOODMAN, P. J. (1968) Physiological analysis of the effects of different soils on sugar-beet crops in different years. *J. appl. Ecol.* **5**, 339–358.

In each of three years sugar beet was grown on seven farms with different soil types, and with two amounts of fertiliser nitrogen. Differences in agricultural yield between the different centres and seasons were associated principally with differences in leaf area index ($L$). These were associated with differences in nitrogen supply from the soils, but also depended on the supply of water.

Net assimilation rate ($E$) varied less than $L$, and $E$ was smaller where yield and $L$ were greater. Regressions of $E$ on $L$ were steeper, and values of $L$ for maximum crop growth rate were probably smaller (about 3) than in earlier experiments. Maximal $L$ is probably attained in most years on the more fertile soils, and hence the annual variation in beet yield probably arises mainly on those soils on which yield is small. The national average yield of sugar beet would be increased if the shortage of nitrogen and water that occur on these soils in some years were relieved.

5.11 HUMPHRIES, E. C. (1968) The effect of growth regulators, CCC and B9, on the protein and total nitrogen of bean leaves (*Phaseolus vulgaris*) during development. *Ann. Bot.* **32**, 497–507.

In developing primary leaves of intact plants of *Phaseolus vulgaris* total-N and protein-N were greatest before the leaves were fully expanded, and treating plants



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with CCC or B9 delayed the subsequent decrease. When the growing point was removed nitrogen continued to accumulate in the leaves until they were fully expanded. Treatment with CCC did not affect the amount of total-N or protein-N in decapitated plants. Apparently nitrogen moves more slowly from primary leaves of CCC-treated plants because the shoot grows more slowly and demands less nitrogen. Similarly, leaves of decapitated plants have more nitrogen because there is no shoot. When primary leaves were detached and rooted, protein continued to increase in them although they were fully expanded before they developed roots, again probably because the demand for nitrogen was small. Changes in protein were correlated with changes in chlorophyll content during development.

Maximum photosynthesis per leaf probably occurs before leaves are fully expanded, and the protein changes in the leaf may be closely related to the trend of photosynthesis during the life of a leaf.

5.12 LEACH, G. J. & WATSON, D. J. (1968) Photosynthesis in crop profiles, measured by phytometers. *J. appl. Ecol.* **5**, 381–408.

The net assimilation rates ($E$) of phytometers were determined at different positions in field crops of barley, winter and spring wheat, potato, sugar beet and kale, to study how the microclimate affecting photosynthesis changes with depth in crop profiles. The phytometers consisted of sugar-beet seedlings grown in the glasshouse in solution culture, selected for uniformity and transferred to the crops for one week. The distributions of leaf area index ($L$) in horizontal layers of the crops, defined by the positions of the phytometers, were also determined, and the light intensity incident on the phytometers was measured in wheat and kale.

Phytometer $E$ decreased with depth in the crop much more rapidly in kale than in spring-sown barley or wheat, and at intermediate rates in the other crops. In cereals and kale, leaf area concentration ($L$ per 10 cm) was greatest near the top of the crop, and small near the ground; in sugar beet it was largest near the middle of the profile, decreasing towards both the top and bottom; in potatoes it increased throughout the profile from top to bottom.

Much of the variation between crop species in the rate of change of phytometer $E$ with depth can be explained by differences in the distribution of crop $L$. When phytometer $E$ was plotted against crop $L$ above the phytometer, the relations were nearly identical for cereals, potato and sugar beet, but phytometer $E$ decreased faster with increase in crop $L$ in kale than in the other crops, suggesting that unit $L$ of kale intercepted more light.

The extinction coefficients of light by leaf area index were not constant throughout the crop profiles. In wheat, they increased with depth, but in kale they were largest near the top of the crop. In the upper part of the crop profiles, where there was most leaf area, the extinction coefficients were larger in kale than in wheat.

A linear regression of phytometer $E$ on mean daily visible radiation ($R$) received by the phytometers at all depths in wheat and kale crops accounted for nearly 90% of the variance of $E$. Separate regressions calculated for wheat and kale were not significantly different. In the range of $R$ found in the crop profiles, the values of $E$ were less than those of phytometers grown under neutral shades receiving $R$ of equal energy. Light penetrating into crop profiles presumably includes a proportion transmitted through leaves, not absorbed by the chloroplast pigments and hence not active in photosynthesis, that increases with depth, and this may explain why the light in crop profiles is less efficient photosynthetically than daylight.



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5.13 SETTY, K. G. H. & WHEELER, A. W. (1968) Growth substances in roots of tomato (*Lycopersicon esculentum* Mill.) infected with root-knot nematodes (*Meloidogyne* spp.). *Ann. appl. Biol.* **61**, 495–501.
(For summary see No. 8.18)

5.14 THORNE, G. N., FORD, M. A. & WATSON, D. J. (1968) Growth, development and yield of spring wheat in artificial climates. *Ann. Bot.* **32**, 425–446.

Spring wheat was grown to maturity in three growth rooms providing: (*a*) 18 hours of light at 20° C and 6 hours of darkness at 15° C (hot long days, HL); (*b*) 18 hours of light at 15° C and 6 hours of darkness at 15° C (cold long days, CL); (*c*) 14 hours of light at 20° C and 10 hours of darkness at 15° C (hot short days, HS). Plants were moved between environments at spikelet initiation and anthesis, so dividing the growth period into three. Mean lengths in days of these periods in the different environments were: Period 1: HL 16, CL 18, HS 25; Period 2: HL 42, CL and HS 61; Period 3: HL 53, CL 83, HS 63. The length of periods 2 and 3 also depended on previous treatments.

Grain dry weight was affected by environmental differences during all periods and effects during successive periods were additive. CL or HS before initiation gave 6% more grain yield than HL by increasing grain number per ear. HS between initiation and anthesis decreased yield by 24% by decreasing the number of grains per spikelet and the proportion of spikelets that contained grain, whereas CL increased it by 21%, by increasing the number of ears. CL after anthesis increased it by 16% because leaves died later, whereas HS decreased it by 14% because there was less radiation and hence less photosynthesis. Dry weight of shoot and root at maturity was increased by CL or HS during periods 1 or 2, and increased by CL and decreased by HS during period 3. The effects on final yield of treatment during periods 1 and 2 were the consequence of similar effects already produced at anthesis, and shoot and root dry weight changed little during period 3.

The effects of environmental differences on grain dry weight could not be explained by differences in leaf-area duration after anthesis ($D_3$), except that CL during period 3 increased both yield and $D_3$ but not proportionately, so that, as with HS, grain:leaf ratio was decreased. Environmental differences during periods 1 and 2 seemed to affect grain weight by altering the capacity of the ear to accumulate carbohydrates, determined by the number of grains per ear, rather than by altering the supply of carbohydrates, determined by $D_3$. Interactions between environments during different periods were usually small compared with the main effects.

5.15 THORNE, G. N., WELBANK, P. J. & BLACKWOOD, G. C. (1969) Growth and yield of six short varieties of spring wheat derived from Norin 10 and two European varieties. *Ann. appl. Biol.* **63**, 241–251.

Five short varieties of spring wheat derived from Norin 10: Lerma Rojo 64A (R), Penjamo 62 (P), Sonora 64 (S), Mexico 120 (M) and an unnamed selection obtained from Mexico (X) had grain yields equal to, or only slightly less than those of the taller European spring varieties Kloka (K) and Jufy I (J). Yields ranged from 500 to 580 g/m² of dry matter. The short variety NBJ 115 (N) was severely infected with yellow rust and yielded only 290 g/m². Total dry weight (excluding roots) of the short varieties was less than of J and K; hence grain accounted for 49% of the total for the short varieties and 42% for J and K. Most of the short varieties had fewer ears than the tall ones because poor germination produced fewer plants. The relative yields of X, P, R and S seemed to be correlated with their plant and ear densities.



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Leaf-area duration after flowering (*D*), based either on total green area or on green area above the flag-leaf node only, was less for the short varieties than for J and K. The apparent mean efficiency of this area in grain production (grain yield divided by *D*) was 50% greater for the short than for the tall varieties.

The height of the short varieties ranged from 43 cm (M) to 79 cm (N). K was 92 cm and J 97 cm tall. Differences in height depended on the lengths of the top four internodes and not on number of internodes. Main shoots of all varieties produced seven or eight leaves. All varieties initiated spikelets 45–48 days after sowing. The short varieties flowered 103 days and matured 155 days after sowing; J and K flowered and matured about 1 week earlier.

5.16 WELBANK, P. J. & WILLIAMS, E. D. (1968) Root growth of a barley crop estimated by sampling with portable powered soil-coring equipment. *J. appl. Ecol.* **5**, 477–481.

The shoots and roots of a barley crop were sampled periodically from 46 days after it was sown until it was ripe (130 days). Root weights were estimated from soil samples 60 cm deep, cut with tubes driven into the soil by a petrol-powered motor breaker.

The roots had reached about 60%, but the shoots only about 20%, of their maximum dry weights by the first sampling (including ears in shoot weights). The root weights increased until 60 or 74 days after sowing and then decreased, but the shoot weights increased more rapidly until 95 days after sowing. The root:shoot ratio therefore decreased with time. Most of the roots were in the top 15 cm of soil; about 12% of the root material recovered was between 15 and 30 cm deep, and about 10% between 30 and 60 cm deep. These fractions changed little during the sampling period. Nitrogen fertiliser up to 0·8 cwt N/acre (100 kg/ha) increased the total weight of roots, mostly in the top 15 cm of soil, but it increased the shoot weights much more, and so decreased the root:shoot ratio.

5.17 WHEELER, A. W. & KING, H. G. C. (1968) Conversion of tryptophan to auxin by phenolic esters from leaves of dwarf French bean (*Phaseolus vulgaris* L.). *Phytochemistry* **7**, 1057–1063.

Macerated bean leaves (*Phaseolus vulgaris*) produced more auxin when incubated at pH 7·5 in the presence of toluene for 2 days with tryptophan than without. Boiled or autoclaved leaves did not produce auxin when incubated alone, but did so after adding tryptophan. Conversion of tryptophan to auxin during incubation of macerated leaves was attributed to phenols, later identified as esters of caffeic, ferulic and *p*-coumaric acids. The phenolic esters extracted from bean leaves promoted growth of wheat coleoptile sections only when assayed with tryptophan, and produced auxin only when incubated or hydrolysed with tryptophan. Caffeic acid, but not ferulic or *p*-coumaric acids, reacted with tryptophan similarly to the bean phenols. Phosphate buffer (pH 7·5) removed phenolic esters, but not auxins, from the surface of bean leaves; as the extracted bean phenols, these produced auxin when incubated with tryptophan.

5.18 WHEELER, A. W. (1969) Effect of CCC and glycine betaine on growth and growth substance content of primary leaves of dwarf French bean (*Phaseolus vulgaris* L.). *Ann. appl. Biol.* **63**, 127–133.

CCC (2-chloroethyltrimethylammonium chloride) decreased growth of primary leaves and stem internodes above the hypocotyl of dwarf French bean, probably because less auxin was produced by interaction between tryptophan and phenolic esters in the primary leaves. Growth of leaves was less affected than of stems, and the gibberellin content of the primary leaves, previously shown to be associated with their expansion, was unaffected by CCC. CCC delayed death



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of the primary leaves, the breakdown of chlorophyll and the increase in auxin associated with death of bean leaves. CCC had less effect on the growth of leaf discs, probably because they do not produce growth substances. Glycine betaine, a quaternary ammonium compound similar to CCC, did not affect growth of bean plants, their metabolism of growth substance or the longevity of their primary leaves, but inhibited growth of leaf discs, probably directly.

5.19 WILLIAMS, E. D. (1968) Preliminary studies of germination and seedling behaviour in *Agropyron repens* (L) Beauv. and *Agrostis gigantea* Roth. *Proc. 9th British Weed Control Conference, 1968*, **1**, 119–124.

The germination of seeds and the emergence and growth of seedlings of *Agropyron repens* (L) Beauv. and *Agrostis gigantea* Roth. were studied in the laboratory and glasshouse. A large percentage of seeds of both species germinated under alternating temperatures, but their response to light was small. Neither species exhibited natural dormancy but dormancy could be induced in *A. gigantea*. When seeds were sown at various depths in pots, seedlings emerged from 4% of *A. repens* seed sown 4 in. deep and 1% of *A. gigantea* sown 2 in. deep. In fertile soil *A. gigantea* grew faster than *A. repens* and was slower to initiate rhizomes. By August *A. repens* seedlings, planted in February, had produced more ears and a greater rhizome dry weight, but fewer shoots, than *A. gigantea*.

## Biochemistry Department

### BOOK

6.1 PIRIE, N. W. (1969) *Food resources: conventional and novel*. Harmondsworth: Penguin Books, 201 pp.

### THESES

6.2 AHMAD, J. I. (1968) The factors governing the release of protein from pulped leaves. Ph.D. Thesis, University of London.

6.3 BUCHANAN, R. A. (1968) Changes in leaf protein preparations during storage. Ph.D. Thesis, University of London.

6.4 HILL, J. M. (1968) Investigations into the nature of the carbonyl component of pea-seedling diamine oxidase, examination of the evidence for the involvement of pyridoxal as a component of the prosthetic group. M.Phil. Thesis, University of London.

### GENERAL PAPERS

6.5 HILL, J. M. (1969) Diamine oxidase (Pea-seedling). In: *Methods in enzymology. Metabolism of amino acids and amines*. Ed. H. Tabor & C. W. Tabor. New York: Academic Press. (In the press).

6.6 HOLDEN, M. (1968) The larger fungi of Rothamsted. *Bull. Br. mycol. Soc.* **2**, 111–118.

6.7 HOLDEN, M. (1969) (editor) Guide to the literature for the identification of British fungi (2nd edition). *Bull. Br. mycol. Soc.* **3**, 19–54.

6.8 PIRIE, N. W. (1967) Foods in the future. In: *Food in the future*. Ed. J. V. McLoughlin. Dublin: An Foras Taluntais, pp. 17–39.



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6.9 PIRIE, N. W. (1968) Work of the U.M. Section of I.B.P. *Times of India*. 13 January.

6.10 PIRIE, N. W. (1968) Leaf protein research in the International Biological Program. *Agric. Sci. Rev.* **5** (4), 17–21.

6.11 PIRIE, N. W. (1968) Implementing the possibilities. In: Symposium 'Feeding the world', *Science Journal* **4**, 101–106.

6.12 PIRIE, N. W. (1968) Introduction to Symposium 'A discussion on anomalous aspects of biochemistry of possible significance in discussing the origins and distribution of life'. *Proc. R. Soc.* (*B*) **171**, 3–4.

6.13 PIRIE, N. W. (1968) Use of plant protein concentrates as human food. In: Symposium 'Food production in the year AD 2000'. *Chemy Ind.*, 864–866.

6.14 PIRIE, N. W. (1968) The development of Haldane's outlook on the nature and origins of life. In: *Haldane and modern biology*. Ed. K. R. Dronamraju. Baltimore: John Hopkins Press, pp. 251–258.

6.15 PIRIE, N. W. (1968) Down-to-earth research. *Ceres* (*FAO Review*) **1**, 26–28.

6.16 PIRIE, N. W. (1968) Food from the forests. *New Scientist* **40**, 420–422.

6.17 PIRIE, N. W. (1968) The viruses. In: *Scientific thought 1900–1960*. Ed. R. Harre. Oxford University Press, pp. 227–237.

6.18 PIRIE, N. W. (1968) The present position of research on the use of leaf protein as a human food. *Proceedings of the International Symposium on protein food and concentrates, Mysore 1967*. (In the press.)

6.19 PIRIE, N. W. (1969) Protein foods of the future. In: *Getting the most out of food*. Van den Berghs. (In the press.)

6.20 PIRIE, N. W. (1969) Possible limitations to the size of free-living organisms. In: *The mycoplasmatales and the L-phase of bacteria*. Ed. L. Hayflick. Appleton-Century-Crofts, pp. 3–14.

6.21 PIRIE, N. W. (1969) Toxic plants and tolerance to plant toxicities. In: *A practical guide to the study of the productivity of large herbivores*. IPB Handbook No. 7. Ed. F. B. Golley & H. K. Buechner. Oxford: Blackwell Scientific Publications, pp. 228–230.

6.22 PIRIE, N. W. (1969) The production and use of leaf protein. *Proc. Nutr. Soc.* **28**, 85–92.

6.23 PIRIE, N. W. (1969) Leaf proteins. In: *Evaluation of novel protein products*, Oxford: Pergamon Press. (In the press.)

RESEARCH PAPERS

6.24 BUCHANAN, R. A. (1969) *In vivo* and *in vitro* methods of measuring the nutritive value of leaf protein preparations. *Brit. J. Nutr.* (In the press.)

Several *in vitro* methods were compared with *in vivo* methods of estimating the



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nutritive value of leaf-protein using a freeze-dried preparation from wheat (A) fresh, (B) after heating moist, (C) after heating moist and then extracting with chloroform and (D) after extraction with an acidified solvent. The treatments had little effect on Biological Value. Heating moist decreased Total Digestibility, Net Protein Utilisation and Protein Efficiency Ratio, but the original values were almost restored by lipid extraction. Acidified solvent extraction decreased TD, NPU and PER of the leaf protein by making it brittle and difficult to wet. Differences in papain solubility and TD were well correlated. Differences in pepsin-pancreatin solubility and TD were less well correlated. Microbiological available amino acid estimations, involving pepsin predigestion, correlated poorly with TD determinations. Unsaturated fatty acids, particularly linolenic, formed complexes during heating of leaf protein. The effect of this on enzyme solubilisation procedures and on digestion *in vivo* is discussed. Some comparisons are made between the effects of heat and extraction with solvents on leaf protein and on fish meal.

6.25 BUCHANAN, R. A. (1969) Effect of storage and lipid extraction on the properties of leaf protein. *J. Sci. Fd Agric.* (In the press.)

At 4° and 28° C leaf protein oxidised, but there was little change in its digestibility, or in the N and P contents of the lipid. After heating at 60° C less lipid could be extracted: a small decrease in digestibility was attributed to heat damage rather than oxidation of the lipid. Losses in digestibility after heating at 100° C were attributed to two different reactions: (*a*) a lipid-complexing reaction depending on moisture content, but not on the presence of oxygen: (*b*) modification of the protein. (*b*) occurred more slowly and depended mainly on the time of heating at 100° C: it did not occur in completely dry protein, was not influenced by the presence of leaf lipid and was not affected by lipid solvent extraction after heating.

The possibility that lipid–protein complexing during preparation of leaf protein causes losses in digestibility is discussed: also similarities between the behaviour during storage of leaf proteins and fish meal.

6.26 BUCHANAN, R. A. & BYERS, M. (1969) Interference by cyanide with the measurements of papain hydrolysis. *J. Sci. Fd Agric.* (In the press.)

KCN, commonly used to activate the proteolytic enzyme papain, may be bound by the Strecker reaction to form cyanohydrins in digestion mixtures. The formation of these N-containing complexes depends on the pH of the digest, incubation time and temperature and the amount of reducing sugar present. They are soluble in 5% trichloroacetic acid, so the N in them will be estimated along with the non-protein N released during digestion. Their formation probably accounts for some experimental discrepancies observed when studying the action of KCN-activated papain on extracted leaf proteins, and calculating the percentage hydrolysis from the amount of N found in the TCA-soluble fraction.

A procedure for digesting leaf proteins by papain is described that uses thioglycollic acid as activator, and the N is estimated in the undissolved substrate and the TCA-precipitable fraction, instead of in the TCA-soluble fraction.

6.27 DAVYS, M. N. G. & PIRIE, N. W. (1969) A laboratory-scale pulper for leafy plant material. *Biotech. Bioengng Res.* (In the press.)

A machine is described that makes, from 2 to 3 kg samples of leaf, a pulp comparable to that made by the large-scale equipment used in leaf-protein extraction. It is therefore suitable for use in experiments on leaf protein yield.



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6.28 DAVYS, M. N. G., PIRIE, N. W. & STREET, G. (1969) A laboratory-scale press for extracting juice from leaf pulp. *Biotech. Bioengng Res.* (In the press.)

A press is described with which loads of up to 1 tonne can be applied quickly to 1 kg quantities of leaf pulp spread over 450 $cm^2$. The juice extracted is similar in quantity and quality to that extracted by large-scale equipment. Evidence is presented that the conditions of pressing are so uniform that the yields of juice are consistent.

6.29 HILL, J. M. (1969) The oxidation of pyridoxal and related compounds by pea-seedling extracts or systems containing peroxidase. (In the press.)

Pyridoxal, pyridoxal phosphate, pyridoxine and pyridoxamine increase the oxygen uptake of pea-seedling extracts in the presence of 1,4-diamino-butane. These increases are greatest with root extracts and are accompanied by a disappearance of pyridoxal or related compounds. Two thermolabile factors in pea-seedling extracts, probably a diamine oxidase (diamine:oxygen oxidoreductase-deaminating, EC. 1.4.3.6) and a peroxidase (donor:hydrogen peroxide oxidoreductase, EC. 1.11.1.7), are involved in this reaction. The diamine oxidase and 1,4-diaminobutane can be replaced by hydrogen peroxide or another system that produced hydrogen peroxide. Pyridoxal and related compounds containing the 3-hydroxypyridine structure are substrates for peroxidase. The 3-hydroxypyridine structure of pyridoxal and pyridoxine is destroyed by incubation with pea-seedling root extracts and 1,4-diaminobutane or with peroxidase and a hydrogen peroxide producing system.

6.30 OLSSON, R. & (BOULTER, D.) (1968) Nucleic acid metabolism of *Vicia faba* during germination and growth. *Physiologia Pl.* **21**, 428–434.

During the growth of *Vicia faba* seedlings in the absence of an external nitrogen supply, the cotyledons decreased rapidly in dry weight and nucleic acid content. In the developing shoot the dry weight increased rapidly for four weeks and then very slowly during the next two; the nucleic acid content increased to a maximum after four weeks growth and decreased during the next two. In contrast, the roots increased in both dry weight and nucleic acid content throughout the growth period, although they accounted for only a small proportion of the total dry weight and nucleic acid content of the plant. These changes during germination and growth are discussed in relation to those occurring during the same developmental stages in other plants.

6.31 OLSSON, R. & (BOULTER, D.) (1968) Nitrogen metabolism of *Vicia faba*. *Physiologia Pl.* **21**, 1029–1036.

*Vicia faba* plants were grown for four and six weeks without externally supplied nitrogen. Some nitrogen moved to the plant axis from the cotyledons throughout this period, but the amount was too small to support maximum shoot growth. During this period the protein content of the shoot declined while the free amino acids, especially aspartic acid, glutamic acid, histidine and the combined pool of threonine, serine, asparagine, glutamine and ammonia increased in amount. In contrast to the shoot, the protein content of the root increased; so did the free amino acid content, though less than in the shoot and only the combined value for threonine, serine, asparagine and glutamine increased significantly. During the last two weeks some soluble non-amino acid compounds seemed to give nitrogen to the pool of free amino acids in the root and the shoot.



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6.32 PIERPOINT, W. S. (1969) o-Quinones formed in plant extracts: their reactions with amino acids and peptides. *Biochem. J.* **112.** (In the press.)

The reactions of amino acids and peptides with the o-quinones produced by the enzymic oxidation of chlorogenic and caffeic acids were studied manometrically and spectrophotometrically. Amino acids, except lysine and cysteine, react primarily through their α-amino groups giving red or brown products. These reactions, which compete with the polymerisation of the quinones, are followed by secondary reactions that may absorb oxygen and produce new colours. The ε-amino group of lysine reacts with the o-quinones in a similar way. The thiol group of cysteine reacts with the quinones, without absorbing oxygen, giving colourless products. Peptides containing cysteine react with the o-quinones through their −SH group. Other peptides, such as glycyl-leucine and leucyl-glycine, react primarily through their α-amino group and the reaction resembles that of the N-terminal amino acid except that it is quicker. With some peptides, the secondary reactions differ from those that occur between the o-quinones and the N-terminal amino acids. The colours produced from carnosine resemble those produced from histidine rather than those from β-alanine, and the reactions of prolyl-alanine with o-quinones are more complex than those of proline.

6.33 PIERPOINT, W. S. (1969) o-Quinones formed in plant extracts: their reaction with bovine serum albumin. *Biochem. J.* **112.** (In the press.)

The reactions between chlorogenoquinone, the o-quinone formed during the oxidation of chlorogenic acid, and bovine serum albumin (BSA), depend on the ratio of reactants. When BSA is in excess, oxygen is not absorbed and the products are colourless. This reaction probably involves the −SH group of BSA; it does not occur with BSA treated with p-chloromercuribenzoate, iodoacetamide or Ellman's reagent. When BSA reacts with excess chlorogenoquinone, oxygen is absorbed and the products are red. The red colour is probably formed by reaction of the lysine ε-amino groups of BSA, as it is prevented by treating the protein with formaldehyde, succinic anhydride or O-methyl isourea. BSA modified by a 1·5-fold (BSA-Q) and a 5-fold (BSA-Q2) excess of chlorogenoquinone were separated by chromatography on DEAE-Sephadex A-50, and some of their properties observed. Reaction of BSA-Q2 with fluorodinitrobenzene suggests that the terminal α-amino group in addition to lysine ε-amino groups, are combined with chlorogenoquinone.

## Plant Pathology Department

### THESIS

7.1 EBBELS, D. L. (1968) The effect of soil sterilants on agricultural crops. Ph.D. Thesis, University of Reading.

### GENERAL PAPERS

7.2 (CUNNINGTON, A. M.) & GREGORY, P. H. Mites in bedroom air. *Nature, Lond.* **217**, 1271–1272.

7.3 GREGORY, P. H. (1968) Interpreting plant disease dispersal gradients. *A. Rev. Phytopath* **6**, 189–212.

7.4 KASSANIS, B. (1968) Satellitism and related phenomena in plant and animal viruses. *Adv. Virus Res.* **13**, 147–180.



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7.5 KLECZKOWSKI, A. (1968) Methods of inactivation by ultraviolet radiation. In: *Methods in virology*. Ed. K. Maramorosch & H. Koprowski. New York: Academic Press Inc., pp. 93–138.

7.6 KLECZKOWSKI, A. (1968) Experimental design and statistical methods of assay. In: *Methods in virology*. Ed. K. Maramorosch & H. Koprowski. New York: Academic Press Inc., pp. 615–730.

7.7 KLECZKOWSKI, A. (1968) 'Mathematical models' for infectivity dilution curves of plant viruses. *Virology* **34**, 186–187.

7.8 KLECZKOWSKI, A. (1968) The multiplicity of bands in the gel diffusion precipitin analysis of the protein of tobacco mosaic virus. *Virology*. **36**, 700–701.

7.9 LACEY, J. (1968) Reader's comment: Farmer's lung. *World Crops* **20**, 56.

7.10 MACFARLANE, I. (1968) Problems in the systematics of the *Olpidiaceae*. *Veröff Inst. Meeresforsch. Bremerh.* Sonderbd. **3**, 39–58.

7.11 MACFARLANE, I. (1968) Transmission of tobacco necrosis virus to higher plants by *Olpidium*—a model for the activities of lower fungi parasitic in algae. *Veröff Inst. Meeresforsch. Bremerh.* Sonderbd. **3**, 133–147.

RESEARCH PAPERS

7.12 BAILEY, L. & MILNE, R. G. (1969) The multiplication regions and interaction of acute and chronic bee-paralysis viruses in adult honey bees. *J. gen. Virol.* **4**, 9–14.
(For summary see No. 11.10.)

7.13 EBBELS, D. L. (1969) Effect of soil fumigation on disease incidence, growth, and yield of spring wheat. *Ann. appl. Biol.* **63**, 81–93.

Plots were fumigated with various amounts of 'D-D' or 85% dazomet dust and sown with spring wheat given various amounts of nitrogenous fertiliser. Dazomet increased yield and decreased take-all disease in the first crop after it was applied, but increased the disease in the second crop. Although 'D-D' increased take-all slightly, it increased yield in 1966, but in 1967 it decreased yield and its use was associated with a severe ear deformity. Fumigation had little effect on eyespot, sharp eyespot, root browning (*Fusarium* spp.) or browning root rot (*Pythium* spp.), but decreased nematode damage where nematodes were numerous.

7.14 GIBBS, A. J., (GIUSSANI-BELLI, G., & SMITH, H. G.) (1968) Broad-bean stain and true broad-bean mosaic viruses. *Ann. appl. Biol.* **61**, 99–107.

Autumn-sown crops of broad beans (*Vicia faba* L.) in England often contain plants with some leaves characteristically distorted and with a mosaic. From some of these plants true broad-bean mosaic virus was isolated in 1959 and 1960 but not in 1965 and 1966. From other plants a similar but distinct virus, which caused staining of the seeds and we call broad-bean stain virus, was isolated in 1960, 1965 and 1966. The two viruses were readily distinguished in serological tests, and in some test plants. Both were seed-borne, and spread in crops, but were not transmitted by several animal species tested as vectors.

Both viruses have isometric particles about 25 mμ in diameter. Some of these particles contain about 35% ribonucleic acid, some about 26% and some of



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those of broad-bean stain virus contain none; these three types of particles had sedimentation coefficients of about 120–130 S, 100 S and 60 S respectively. The ribonucleic acid of each virus had molar base content of G 23%, A 26%, C 18% and U 32%.

These two viruses are members of the cowpea mosaic group of plant viruses; broad-bean stain virus is serologically related to cowpea mosaic, F I, red-clover mottle and squash mosaic viruses. The particles of all these, and of true broad-bean mosaic virus, have similar appearances, sedimentation behaviour, and nucleic acid content and composition. The nucleic acid of red-clover mottle virus had a molar base content of G 20%, A 29%, C 20%, U 30%.

7.15 HARRISON, B. D. (1968) Reactions of some old and new British potato cultivars to tobacco rattle virus. *Eur. Potato J.* **11**, 165–176.

Fourteen potato cultivars were grown on sandy land in Norfolk infested with *Trichodorus pachydermus* carrying tobacco rattle virus (TRV). Four out of five old cultivars showed few or no symptoms of spraing, whereas six out of nine modern cultivars were moderately or severely affected. In cultivars that showed severe spraing, TRV rarely passed from affected tubers to progeny plants and tubers, but did so more often in cultivars that showed slight spraing. Haulm symptoms in progeny plants consisted of stem-mottle, sometimes including figure aucuba. Some of the tubers produced by plants with stem-mottle showed internal markings whose severity was related to that of the primary spraing in that cultivar. Arran Pilot showed neither spraing nor stem-mottle; its roots resisted infection by vector-borne TRV, but its leaves were infected by manual inoculation with infective sap. TRV was transmitted by inoculation of sap to indicator plants from more than 90% of freshly dug tubers showing spraing, and of shoots showing stem-mottle.

7.16 HICKMAN, A. J. & VARMA, ANUPAM (1968) Viruses in horseradish. *Pl. Path.* **17**, 26–30.

Of forty-seven clones of horseradish tested, originating from several different countries, 30 contained sap-transmissible viruses; arabis mosaic virus was obtained from 53% of the clones, cabbage black ring spot virus from 36% and cauliflower mosaic virus from 13%. Apical meristem culture freed a clone from cabbage black ring spot and cauliflower mosaic viruses.

7.17 HIDE, G. A., HIRST, J. M. & SALT, G. A. (1968) Methods of measuring the prevalence of pathogenic fungi on potato tubers. *Ann. appl. Biol.* **62**, 309–318.

Methods are described whereby the prevalence of pathogenic fungi on seed potato tubers can be measured quickly and quantitatively. Eye-bearing plugs of tuber tissue, 8 mm diameter by 10 mm long, are excised, incubated over water at 15° C for 5 days and then examined microscopically. The occurrence of fungi and macroscopic tuber symptoms are recorded directly on punched tape and tabulated by computer.

7.18 KASSANIS, B. & WOODS, R. D. (1968) Aggregated forms of the satellite viruses of tobacco necrosis virus. *J. gen. Virol.* **2**, 395–398.

The several kinds of the two- and three-dimensional crystalline forms produced by the satellite virus of tobacco necrosis virus are described and discussed.

7.19 KASSANIS, B. & MACFARLANE, I. (1968) The transmission of satellite viruses of tobacco necrosis virus by *Olpidium brassicae*. *J. gen. Virol.* **3**, 227–232.

None of four isolates of *Olpidium brassicae* (Wor.) Dang. (*Olpidia* 1, 2, 3 and 6)



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transmitted the original strain of satellite virus (SV 1). Two strains of satellite virus recently isolated (SV 2 and SV 3) were both transmitted, but SV 2 only by *Olpidium* 6 and SV 3 only by *Olpidium* 3. Hence different isolates of *Olpidium* seem to be specific vectors for different strains of satellite virus.

7.20 KLECZKOWSKI, A. (1968) Dark reactivation of ultraviolet-irradiated tobacco necrosis virus. *J. gen. Virol.* **3**, 19–24.

Some damage caused in tobacco necrosis virus by u.v. radiation could be repaired in darkness in *Chenopodium amaranticolor* (dark reactivation) but not in French bean or in tobacco. By contrast, the irradiated virus was photoreactivated in French bean and in tobacco but not in *Chenopodium*. The kind of damage in u.v.-irradiated virus that is susceptible to repair by photoreactivation seems to be repaired by dark reactivation in *Chenopodium*. In conditions without evidence of any repair, the quantum yield for inactivation of the nucleic acid inside the virus is about $6{\cdot}5 \times 10^{-4}$, and the amount of radiation energy that must be absorbed by the nucleic acid to halve infectivity is about 0·3 J/mg.

7.21 LAPWOOD, D. H. (1968) Infection of potato tubers by common scab (*Streptomyces scabies*) during brief periods when soil is drying. *Eur. Potato J.* **11**, 177–187.

Plots of chitted and unchitted Majestic seed planted in soil naturally infected with *Streptomyces scabies* were trickle irrigated to prevent infection except during 5, 10 or 15 days from when plants from unchitted seed began to form tubers.

At harvest, scab was most severe on the tubers of plants unwatered for 10 or 15 days. Tubers from unchitted seed were scabbed mostly at the attachment end; those from chitted seed had a band of lesions around their middle. On average, 4, 5 and 6 tuber internodes were scabbed, respectively, for 5, 10 and 15 days without irrigation, because only the one new internode formed during each of the 5 day periods, and the last two or three internodes formed before irrigation stopped, were susceptible to infection when soil was allowed to dry. Tubers from unchitted seed showed most blemish because attachment end internodes constitute much of the surface area of mature tubers.

7.22 MACFARLANE, I., (JENKINS, J. E. E. & MELVILLE, S. C.) (1968) A soil-borne virus of winter oats. *Pl. Path.* **17**, 167–170.

A mosaic of winter oats in Devon was caused by a virus that is soil-borne, transmissible by sap inoculation and has long particles (*ca.* 700 × 12 nm). These particles, which were found only in sap from the chlorotic lesions, suggest oat-mosaic virus, previously unrecorded in Great Britain.

7.23 SNYDER, W. C. & NASH, S. M. (1968) Relative incidence of *Fusarium* pathogens of cereals in rotation plots at Rothamsted. *Trans. Br. mycol. Soc.* **51**, 417–425.

Soil samples were collected from plots on Broadbalk, Hoosfield and Barnfield and from Broadbalk Wilderness, and their *Fusarium* content was estimated by plating on the Nash medium, selective for *Fusarium*. At the same time isolations of *Fusarium* were made from diseased wheat and barley plants where present in the plots. Of the *Fusarium* pathogens recovered, *F. roseum f. cerealis* 'Culmorum' was abundant, i.e. 2000–3000 or more propagules per g of soil in Broadbalk continuously sown to wheat, and the same fungus was recovered from brown lesions on culms of wheat growing in these plots. The most 'Culmorum' occurred where complete fertilisation, including much nitrogen, had been applied, and fewest where fertiliser had not been used. On Barnfield, where only broad-leaved crops have been grown for more than 100 years, and in Broadbalk Wilderness,



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'Culmorum' was very rare. Although *F. nivale* and its perithecial state, *Calonectria nivalis*, were commonly isolated from fusarium-infected wheat and barley plants at Rothamsted, in addition to *F. roseum* 'Culmorum', the snow mould *Fusarium* was not recovered from the soil. This agrees with the fact that *F. nivale* does not normally form chlamydospores, whereas 'Culmorum' produces them abundantly and therefore is ideally soil-borne.

## Nematology Department

### Theses

8.1 Evans, K. (1968) Influence of some factors on the reproduction of *Heterodera rostochiensis*. Ph.D. Thesis, University of London.

8.2 Setty, K. G. H. (1968) Studies on the biology and host-parasite relationships of root-knot nematodes (*Meloidogyne* spp.). Ph.D. Thesis, University of London.

8.3 Trudgill, D. L. (1968) The effect of environment on sex determination in *Heterodera rostochiensis*. Ph.D. Thesis, University of London.

### General Papers

8·4 Hooper, D. J. (1969) Extraction and handling of plant and soil nematodes. In: *Nematodes of tropical crops*. Ed. J. E. Peachey. *Tech. Commun. Commonw. Bur. Helminth.* No. 40. (In the press.)

8.5 Hooper, D. J. (1969) Identification of plant and soil nematodes. In: *Nematodes of tropical crops*. Ed. J. E. Peachey. *Tech. Commun. Commonw. Bur. Helminth.* No. 40. (In the press.)

8.6 Hooper, D. J. (1969) Some problems in the systematics of soil nematodes. In: *The soil ecosystem*. Ed. J. G. Sheals & P. W. Murphy. (*Publ. Systematics Ass. No. 8.*) (In the press.)

8.7 Jones, F. G. W. (1968) Some comments on population dynamics and pathotypes of *Heterodera rostochiensis*. *Proc. N.W. Nematology Workshop, Vancouver, 1968*, pp. 35–38.

8.8 Jones, F. G. W. (1969) Some reflections on quarantine, distribution and control. In: *Nematodes of tropical crops*. Ed. J. E. Peachey. *Tech. Commun. Commonw. Bur. Helminth.* No. 40. (In the press.)

8.9 Whitehead, A. G. (1969) Nematodes attacking coffee, tea and cocoa and their control. In: *Nematodes of tropical crops*. Ed. J. E. Peachey. *Tech. Commun. Commonw. Bur. Helminth.* No. 40. (In the press.)

8.10 Williams, T. D. (1968) Plant parasitic nematodes. In: *Plant pathologists handbook*. Kew: Commonwealth Mycological Institute, pp. 119–136.

### Research Papers

8.11 Clarke, A. J. (1968) The chemical composition of the cyst wall of the potato cyst-nematode, *Heterodera rostochiensis*. *Biochem. J.* **108**, 221–224.

Cyst walls of the potato cyst-nematode (*Heterodera rostochiensis* Woll.) were isolated by sieving a suspension of crushed cysts. About 12 mg of dried cyst walls



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was obtained from 1000 cysts. The cyst walls contained mainly protein (72%, calculated from nitrogen content). On acid hydrolysis about 77% of the cyst wall dissolved. Of nineteen amino acids present, proline, glycine and alanine were the most abundant, and made up about 50% by weight of the total amino acids. The amino acid composition suggested that collagen-like proteins predominated in the cyst wall and larval cuticle. Other components of the cyst walls were lipid (2%), carbohydrate (0·5%) and a small amount of inorganic matter (ash, 5%), but not chitin. The hydrolysates combined polyphenols (2% by wt. of the cyst walls) and glucosamine (1·5%). The dark pigments of the cyst wall were not indole-containing melanins.

8.12 FISHER, J. M. (1969) Investigations on fecundity of *Aphelenchus avenae*. *Nematologica*, **15**, 22–28.

*Aphelenchus avenae* feeding on fungal cultures in Petri dishes responded to adverse conditions by slowing egg laying, not by laying fewer eggs. The females required a continuous supply of food to produce eggs; after starving they resumed egg laying when given food and laid at the same rate as unstarved individuals and for the same length of time. The different hosts tested did not affect the average number of eggs laid per female but did affect the rate eggs were laid. Individual females laid more eggs when there were four in a Petri dish than when they were alone.

8.13 FISHER, J. M. (1969) The relation between stylet and body length in *Aphelenchus avenae* with observations on *Paratylenchus nanus*. *Nematologica* **15**. (In the press.)

The body length and breadth of adult *Aphelenchus avenae* increased or decreased with food supply but stylet length remained unchanged. Correlations between stylet and body length were slight except in newly-moulted specimens and depended on the extent to which body length had changed after moulting. Initially body length and breadth depended partly on the duration of feeding in the fourth-stage larvae. Later correlations between body length and breadth were greater and varied less with changes in size of the body. Adult females of *Paratylenchus nanus* have a similar relation between stylet and body length to that of *Aphelenchus avenae*, so there is little dependence of stylet length on body length. Geraert's classification of *Paratylenchus*, which relies on the stylet length and body length being fully correlated, is partly based on invalid criteria.

8.14 GREET, D. N., GREEN, C. D. & (POULTON, M.) (1968) Extraction, standardisation and assessment of the volatility of the sex attractants of *Heterodera rostochiensis* (Woll.) and *H. schachtii* Schm. *Ann. appl. Biol.* **62**, 511–519.

A bioassay using five males of *Heterodera* spp. on an agar plate was sensitive enough to estimate the relative concentrations in washings of females of substances attractive to males. It showed that these substances include volatile components able to diffuse through air and accumulate on agar blocks.

8.15 (JAIRAJPURI, M. S.) & HOOPER, D. J. (1969) The genus *Longidorella* Thorne. *Nematologica* **15**. (In the press.)

The genera *Enchodorella* and *Thornedia* are synonymised with *Longidorella*, which is retained in Nordiinae, Dorylaimidae. Observations are made on specimens of *Longidorella parva* from Malawi, India and E. Pakistan; *L. xenura*, *L. murithi* and *L. hastata* from India; *L. penetrans* from U.S.A., *L. europaea*, *L. macramphis* and *L. ?tredecima* from England. Tail shape and also the shape



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and structure of the junction between the anterior slender part and the expanded basal part of the oesophagus varied within and between species.

8.16 JONES, F. G. W., LARBEY, D. W. & PARROTT, D. M. (1969) The influence of soil structure and moisture on nematodes, especially *Xiphinema*, *Longidorus*, *Trichodorus* and *Heterodera* spp. *Soil Biol. Biochem.* **1**. (In the press.)

In soils, space and moisture are critical factors determining their suitability for nematodes, which may squeeze through necks with diameters somewhat smaller than their own, but the diameter of the necks determines whether they can pass between spaces. The mean free path that can be traversed before encountering blind ends, or impassable holes, is probably also important, especially for long nematodes. Studies of artificial soils composed of uniform spheres have little relevance to the penetration of soil spaces by nematodes but suggest that, except in coarse soils, nematodes cannot penetrate the spaces between particles and are confined to spaces between aggregates.

In an untilled woodland soil containing much clay, *Xiphinema diversicaudatum* was seen in macropores between impenetrable aggregates. The amount of usable space in the soil was estimated from the moisture characteristics of samples taken down the profile. At 2, 6, 18 and 30 in., 13, 8, 6 and 5% of the soil volume was usable and the decrease with depth corresponded with increasing amounts of clay.

*Heterodera* spp. occurred in fine and coarse textured soils, but *Trichodorus* and *Longidorus* spp. were rare except in soils with 80% or more of coarse particles (fine and coarse sand). Tillage increases the amount of space usable by nematodes, even in fine soils with much clay. Weathering and cultivations may break down aggregates and decrease usable space. Some tilled soils with weak aggregates contain particles of such shapes and sizes that they readily compact to a system with few inter-connecting pores of a size through which nematodes can pass. Coarse sandy soils are unstable and tend to compact but even when partly compacted provide space for *Trichodorus* and *Longidorus* spp. to move.

Whereas ectoparasitic nematodes live in the soil, endoparasitic ones soon leave it to enter plant-roots where they are less affected by soil moisture. As coarse soils soon drain and as nematodes can function only when structural moisture forces are small, rain is probably important to ectoparasitic species. The summation of nematode activity is probably related to cumulative rainfall. Dry spells during May probably immobilise nematodes long enough for damaged root systems to recover and allow plants to grow.

The influence of soil moisture on the multiplication of seven species of *Heterodera* was studied in microplots. After five years, *H. rostochiensis* and *H. goettingiana* were well established, but *H. avenae* was not even after growing cereal hosts for eight years. Rainfall was probably adequate in all years. Poor moisture retention did not limit *H. rostochiensis* or *H. goettingiana* and, unless they have greatly different moisture requirements, probably did not limit the other species. *H. schachtii* fails to multiply in Cantley soil probably because it compacts and then has few interconnecting spaces suitable for nematodes.

8.17 JONES, F. G. W. & PARROTT, D. M. (1969) Population fluctuations of *Heterodera rostochiensis* Woll. when susceptible potato varieties are grown continuously. *Ann. appl. Biol.* **63**, 175–181. (In the press.)

When seven potato varieties susceptible to *H. rostochiensis* were grown every year on the same small plots for six years with precautions to minimise soil movements, yields were inversely proportional to the number of larvae in the soil before cropping in the first year only. With all the varieties, numbers of larvae



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after harvest fluctuated around mean values and the fluctuations became smaller in successive years. Although conditions from year to year were as uniform as possible, there were differences in weather, incidence of potato blight (*Phytophthora infestans*), seed size and quality, and in planting dates. Analysis of soil temperatures and of heat accumulation did not suggest that conditions after planting caused the fluctuations. The smaller fluctuations with repeated cropping probably reflect the influence of population density on the size of the root system and are what would be expected from the curve relating pre- to post-cropping numbers, which reach a maximum before the reproductive rate decreases to unity.

A resistant potato hybrid ex *andigena*, also grown every year, usually outyielded the susceptible varieties and, by the sixth year, yielded at least twice as much as the mean of the six susceptible varieties.

8.18 SETTY, K. G. H. & WHEELER, A. W. (1968) Growth substances in roots of tomato (*Lycopersicon esculentum* Mill.) infected with root-knot nematodes (*Meloidogyne* spp.). *Ann. appl. Biol.* **61**, 495–501.

Roots of tomato plants with galls caused by larvae of *Meloidogyne* spp. contained a similar concentration of auxin as uninfected roots, but a larger total amount because the roots of infected plants were heavier. The body contents and saliva or excretions of *M. incognita* larvae contained too little auxin to account for the increased amounts in infected roots. Roots with galls contained more bound auxin, released by alkaline hydrolysis or incubation after maceration, and more tryptophan and other amino acids, than uninfected roots. The larvae may hydrolyse the plant proteins to yield tryptophan, which may then react with the endogenous phenolic acids to produce auxin.

8.19 WEBSTER, J. M. (1967) Some effects of 2,4-dichlorophenoxyacetic acid herbicides on nematode-infested cereals. *Pl. Path.* **16**, 23–26.

After spraying an aqueous solution of 2,4-dichlorophenoxyacetic acid, 2,4-D (140 mg/100 ml/sq yd) on nematode susceptible (cv. Sun II) and resistant (cv. Manod) oats infested with *Ditylenchus dipsaci*, the final number of nematodes per plant after eight weeks, in both resistant and susceptible varieties was greater in the sprayed than in the unsprayed plants. Seedlings (18 days old) sprayed two weeks after inoculation with nematodes usually contained most nematodes. Spraying 'Shell D50', a commercial 2,4-D herbicide (1·0 ml of concentrate/250 ml/4 sq yd), on nematode-infested oats increased the number of nematodes per plant but not significantly. The 2,4-D spray, which decreased the resistance of oats, but not of barley, to nematodes, caused plant cell hypertrophy and proliferation, which is a necessary response for nematodes to develop.

8.20 WEBSTER, J. M. & DONCASTER, C. C. (1968) Clumping of the plant parasitic nematode *Ditylenchus dipsaci* in water. *Nematologica* **14**, 131–136.

Aggregation of *D. dipsaci* in deep water seems to depend initially on external factors to bring the nematodes into close contact with one another. Clumping does not depend on sensory attraction. A proportion of the nematodes present must be active to form clumps by random interlocking. Accretion of clumps is by chance entry of nematodes whose movement is thereby restrained and by actively 'hooking' nematodes within the clump becoming interlocked with some outside it. Clumps are essentially dynamic aggregations and weak convection currents can favour clumping or dispersion according to their direction relative to the largest densities of nematodes.



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8.21 WEBSTER, J. M. & HOOPER, D. J. (1968) Serological and morphological studies on the inter- and intraspecific differences of the plant-parasitic nematodes *Heterodera* and *Ditylenchus*. *Parasitology* **58**, 879–891.

Saline extracts of species of *Ditylenchus* and *Heterodera* initiated antibody production when inoculated separately into rabbits. On agar gel diffusion plates these antisera gave a precipitate response against their homologous extracts and against extracts of some of the other nematode species. Up to four precipitation bands occurred indicating the presence of at least four distinct antigens. Antisera to these extracts did not precipitate against extracts of the host plant or against the extracts of nematodes from other genera. None of the nematode extracts precipitated against normal serum. The precipitation response divided the *Heterodera* species tested into two groups, one containing *H. schachtii*, *H. trifolii* and *H. rostochiensis* and the other containing *H. cruciferae*, *H. carotae* and *H. goettingiana* with apparently no antigens common to both groups. The three species of *Ditylenchus* were serologically distinct, and it was not possible to interbreed *D. myceliophagus* and *D. destructor*. The extent of the postvulval sac was the most useful morphological character for separating *D. myceliophagus* from *D. destructor*. Only slight intraspecific serological differences were detected between five races (narcissus, oat, red clover, tulip and giant) of *D. dipsaci* and between the two pathotype populations (Colyton and Woburn) of *H. rostochiensis*. Precipitates occurred at the excretory pore of living larvae and adults of *Ditylenchus* species and at the vulval aperture of white females of *Heterodera* species placed in their homologous antisera.

8.22 WHITEHEAD, A. G. (1969) The distribution of root-knot nematodes (*Meloidogyne* spp.) in tropical Africa. *Nematologica* **15**. (In the press.)

*M. javanica* and *M. incognita* are the commonest species of *Meloidogyne* in arable land in East Africa from sea level to 7000 ft, in the Amboim region of Angola and in the Zaria region of Northern Nigeria, but they are rare in coffee and pyrethrum. *M. incognita* is commoner than *M. javanica* at low altitudes, but at high altitudes and at intermediate altitudes with ample rainfall *M. javanica* is the commoner species.

*M. hapla* is common in East Africa only on pyrethrum, which is grown between 6000 and 9000 ft. In pepper roots *M. incognita* is common but *M. javanica* is rare. Tobacco is more susceptible in East Africa to *M. javanica* than to *M. incognita*.

*M. decalineata*, *M. africana*, *M. megadora* and three undescribed species of *Meloidogyne* infested coffee roots, and with *M. kikuyensis* and *M. ethiopica*, are probably indigenous African species.

*M. arenaria*, *M. artiellia*, *M. exigua*, *M. brevicauda*, *M. coffeicola*, *M. graminis*, *M. indica*, *M. ovalis* and *M. thamesi* have not been found in East African cultivated soils.

## Insecticides and Fungicides Department

### GENERAL PAPERS

9.1 ELLIOTT, M. (1968) The search for safer insecticides. *Features Newsletter* No. 5. Central Office of Information.

9.2 NEEDHAM, P. H. & STEVENSON, J. H. (1967) Bee poisoning in 1967. *Bee Wld* **48** (4), 120.

9.3 PHILLIPS, F. T. (1968) Microencapsulation: a method for increasing specificity and controlling persistence of pesticides. *PANS*, Sect. A **14**, 407–410.



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## Research Papers

9.4 Arnold, A. J. (1968) A versatile gas/liquid valve. *J. scient. Instrum.* **2**, 563–564.

A glandless full flow control valve suitable for the rapid switching of slurry, particles, liquids or gases is described. The valve was developed to enable a sample of dead insects collected in alcohol to be removed from the base of a conical vessel with the minimum quantity of carrier liquid, and later used for switching particles in suspension into different channels. Complete cut-off was achieved with gauge pressures up to 60 lb in.$^{-2}$

9.5 Arnold, A. J. (1968) A portable counter with keyboard and probes. *Lab. Pract.* (In the press.)

A portable counter unit with keyboard and probes designed to count particles is described and its operation explained. A keyboard and four counter-unit permits the simultaneous recording of different phenomena and a total count to be registered. The high input impedance of this unit enables counting to be made over large areas of low conductivity. When counting lesions on leaves the leaf can usually be made one electrode, and with a felt-tip pen as a conducting probe the lesions can then be coloured as they are counted.

9.6 Banks, C. J. (1968) Effects of insect predators on small populations of *Aphis fabae* in the field. *Ent. exp. appl.* **11**, 169–176.

Predators (mostly staphylinid larvae) almost completely eliminated small initial colonies of *Aphis fabae* on beans (*Vicia faba*) in the field during a summer unfavourable to the aphid's rapid multiplication. Syrphid larvae must have travelled considerable distances from other plants. A method of labelling single apterous adult aphids with a radioisotope for their detection in the field is described.

9.7 Banks, C. J., Macaulay, E. D. M. & (Holman, J.) (1968) Cannibalism and predation by aphids. *Nature, Lond.* **218**, 491.

Aphids are usually regarded as feeding exclusively on plant sap which they ingest through stylet-like mouth parts, but they have occasionally been seen to feed on animal food. During feeding on a turgid plant, they do not have to suck, but depend chiefly on the pressure of the sap for ingestion. They can, however, suck through artificial membranes on food that is under negligible pressure. This communication collates records of cannibalism and predation among aphids.

9.8 Burt, P. E. & Lord, K. A. (1968) The influence of penetration, distribution, sorption and decomposition on the poisoning of the cockroach *Periplaneta americana* treated topically with diazoxon. *Ent. exp. appl.* **11**, 55–67.

Microchemical techniques were used to assess the rate diazoxon penetrates into the American cockroach *Periplaneta americana* L., by measuring loss from the surface of the cuticle after topical application. The proportions of the amount entering that were decomposed, absorbed by the tissues or circulating in the haemolymph were also estimated. About three-quarters of an LD90 of diazoxon (2·6 μg) applied to the metathoracic sternum of adult male cockroaches had penetrated the cuticle 2 hours after treatment. The maximum concentration within the cockroach, reached about 1 hour after treatment, was 2·4 μM, but two-fifths of this is sorbed on solids, leaving 1·4 μM in the total body fluids. The maximum concentration in the haemolymph occurred 1½ hours after treatment and ranged from 0·9 to 3·4 μM, with a 'median' value of 1·8 μM. The close relationship between concentration in haemolymph and in total body fluids suggests that they are in approximate equilibrium.



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An independent estimate of the concentration of diazoxon in the haemolymph of cockroaches treated with an LD90 of the insecticide, made by an electrophysiological technique, agreed well with the values obtained from the chemical assay. The maximum concentration (0·6–1·0 μM) was found 1–2 hours after treatment, when the nervous system is first irreversibly damaged.

The close agreement between the chemical and biological estimates suggests that diazoxon invades the nerve cord from the haemolymph, and that it acts directly, rather than as a metabolite or by the release of a neuroactive material.

9.9 BUTLER, C. G. & CALAM, D. H. (1969) Pheromones of the honeybee – the secretion of the Nassanoff gland of the worker. *J. Insect Physiol.* **15,** 237–244. (For summary see No. 11.12.)

9.10 BUTLER, C. G. & CALLOW, R. K. (1968) Pheromones of the honeybee (*Apis mellifera* L.): the 'inhibitory scent' of the queen. *Proc. R. ent. Soc. Lond.* (*B*) **43**, 62–65.
(For summary see No. 11.13.)

9.11 CALAM, D. H. (1968) n-Alkanes of the English 'oak apple'. *Phytochemistry* **7**, 1419–1420.

From the 'oak apple', the gall produced by *Biorhiza pallida* (Olivier), a mixture was isolated (0·42%) consisting of all the saturated, straight-chain alkanes from $C_{18}H_{38}$ to $C_{31}H_{64}$. The main components are the $C_{25}$ (42%), $C_{27}$ (22%), $C_{23}$ (18%) and $C_{29}$ (16%) compounds.

9.12 CALAM, D. H. & YOUDEOWEI, A. (1968) Identification and functions of secretion from the posterior scent gland of fifth instar larvae of the bug *Dysdercus intermedius*. *J. Insect Physiol.* **14**, 1147–1158.

Secretion from the posterior scent gland of fifth instar larvae of *Dysdercus intermedius* Dist. (Hemiptera: Pyrrhocoridae) was analysed by a combination of gas chromatography and mass spectrometry. Eight compounds, usually comprising more than 99·9% of the secretion, were identified: *n*-dodecane, *n*-tridecane, *n*-pentadecane, hexanal, hex-2-en-1-al, 4-oxohex-2-en-1-al, oct-2-en-1-al and 4 oxo-oct-2-en-1-al. Traces of four additional components were occasionally present.

The whole secretion, but not its constituent hydrocarbons, causes *D. intermedius* to disperse from its aggregations. Hexanal and *trans*-hex-2-en-1-al, although minor components of the secretion, also produce this effect and seem to be the first alerting pheromones identified in the Hemiptera. The secretion may possess two functions: (1) as a defence against predators and (2) as an alerting pheromone, warning and dispersing other individuals in an aggregation.

9.13 (COOPER, B. A.), NEEDHAM, P. H. & STEVENSON, J. H. (1968) The value of a fluorescent tracer in determining the quantity of dieldrin on honeybees foraging in a sprayed crop. *J. apicult. Res.* **7**, 47–50.

Honeybees foraging on plants sprayed with 'Dieldrex 15' containing Saturn Yellow, a fluorescent pigment, were collected in front of, or within, the hive at intervals after spraying, and grouped according to the amount of fluorescent tracer on them. Estimation of their dieldrin content by gas/liquid chromatography indicated that, whether the bees were collected inside or outside the hives at different times after spraying, their dieldrin contents increased with increasing amounts of pigment. The amount of pigment did not indicate their absolute dieldrin contents, and could not be used to compare the relative amounts of dieldrin in bees collected at different places.



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9.14 ELLIOTT, M. & JANES, N. F. (1969) Pyrethrin II and related esters obtained by reconstitution. *Chem. Ind.* 270–271.

The pyrethric acid chloride fraction produced from the mixed esters of the natural pyrethrins by alkaline saponification contains some chrysanthemum dicarboxylic acid dichloride. However, recrystallisation of this material from *n*-pentane removes the diacid chloride and pyrethrin II reconstituted from recrystallised pyrethric acid chloride is therefore free from isomers.

9.15 JEFFS, K. A., LORD, K. A. & (TUPPEN, R. J.) (1968) Insecticides on single seeds treated with liquid dressings. *J. Sci. Fd Agric.* **19**, 195–198.

A method for determining insecticide on seeds treated with liquid formulations, by extraction and gas chromatography of the extract, was devised and used to estimate the amount of the insecticide on single seeds.

Eight solvents were tested for their ability to extract aldrin from wheat seeds treated with a liquid formulation. Acetone-hexane was chosen for further investigation because in 24 hours at room temperature it extracted at least 95% of the aldrin from treated seeds. This solvent almost quantitatively extracted chlorfenvinphos and carbophenothion at room temperature and $\gamma$-BHC at 45° C in 24 hours, without extracting substances that interfere with gas chromatography of the insecticides.

The amount of insecticide found on single seeds varied widely, in seeds dressed both in the laboratory with commercial preparations (range 4- to 7-fold) and in two commercial plants (range 40- to 200-fold).

9.16 GRAHAM-BRYCE, I. J. (1968) Movement of systemic insecticides through soil to plant roots. *S.C.I. Monogr.* No. 29, 251–267.

This paper describes investigations to determine if rates of movement through soil to roots limit uptake by plants of the systemic insecticides disulfoton (diethyl *S*-[2-(ethylthio)ethyl]phosphorothiolothionate) and dimethoate (dimethyl *S*-(*N*-methylcarbamoylmethyl)phosphorothiolothionate) when the insecticide is uniformly mixed with soil. Uptake was investigated at soil concentrations shown by bio-assay with aphids (*Rhopalosiphum padi* (L.)) to produce toxic concentrations in wheat. The amounts of radiotracer taken up by wheat from soil, treated with $^{32}$P-labelled dimethoate and disulfoton at these concentrations, were measured during 4 weeks' growth in controlled environment rooms. These amounts were compared with calculated quantities reaching the roots by transport in the soil solution and diffusion along concentration gradients. Amounts transported in the soil solution which moves to the root in response to transpiration were estimated from the product of volume of water transpired and solution concentration. Transpiration was estimated from weights of shoot produced by the wheat and solution concentrations were calculated from adsorption isotherms. Comparison of calculated and experimentally measured quantities suggests that much more dimethoate reached the roots by transport in the soil solution than was taken up, whereas uptake of disulfoton was similar to the quantity brought to the roots. Diffusion coefficients ($D$) at different concentrations were measured by determining the distribution of insecticide in a column of soil after diffusion from one half of the column to the other for a known time. $D$ varied little with concentration and average values at 17% v/v water content for the Lower Greensand soil used were $3{\cdot}14 \times 10^{-7}$ cm$^2$ sec$^{-1}$ for dimethoate and $2{\cdot}62 \times 10^{-8}$ cm$^2$ sec$^{-1}$ for disulfoton. Using these figures, calculations of insecticide diffusing to a model root suggest that much more dimethoate and disulfoton could reach the root by diffusion than was taken up by the plant. It is concluded that when either of these insecticides, which have contrasting physical properties and affinities for



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soil is uniformly incorporated in soil, transport to roots is not likely to limit uptake.

9·17 GRIFFITHS, D. C. & SCOTT, G. C. (1969) Timing of insecticidal sprays to control wheat-bulb fly (*Leptohylemyia coarctata* Fall.). *Bull. ent. Res.* (In the press.)

The timing of sprays in relation to the stage of development of wheat plants and Wheat Bulb fly larvae was studied in the laboratory and field. The main growth of young wheat plants was of the centre shoot and such plants died when the centre shoot meristems were destroyed. Older plants survived by growth of lateral shoots. Sprays of dimethoate, trichloronate and thionazin applied before the larvae had emerged did not kill many larvae in the soil, and only insecticide that entered the plants was effective. Severely attacked 2-leaf plants yielded little whether sprayed or not, whereas 3-leaf plants sprayed in early March gave a worthwhile increase in yield; older plants had enough shoots to give moderate yields even when not sprayed.

In a large field trial, plants from two sowing dates, 22 October and 1 November, were both at the late 2-leaf stage of growth in late February. Wheat Bulb fly larvae had entered nearly all the shoots but plants from both sowings had buds or small lateral growths hidden beneath the outer leaves. The yields of October-sown plots sprayed on 22 February, 2 March, 9 March or 16 March were 28·2, 28·8, 25·5 and 23·2 cwt/acre respectively (yield of unsprayed plots = 18·9 cwt/acre) and of November-sown plots were 31·0, 27·5, 17·9 and 14·9 cwt/acre respectively (yield of unsprayed plots = 11·6 cwt/acre). Sprays had most effect when applied soon after larvae had entered the plants. Spraying severely-attacked late 2-leaf to 3-leaf plants gave the greatest benefits because these plants recovered by growth of lateral buds or small lateral shoots.

9.18 HENDERSON, I. F. (1968) Laboratory methods for assessing the toxicity of contact poisons to slugs. *Ann. appl. Biol.* **62**, 363–369.

Two techniques for comparing the activity of different contact poisons to slugs in controlled conditions were used to measure the relative toxicities of five substances. A laboratory immersion test rated their median lethal concentrations as follows: ioxynil 8·3 ppm, sodium pentachlorophenate 22·0 ppm, copper sulphate 68·1–75·3 ppm, acetaldehyde 4822 ppm. Metaldehyde gave inconsistent results with this method but, using a dry-contact method, metaldehyde (42370 ppm) was much less toxic than copper sulphate (2027 ppm). The materials giving practical control in the field were not the most toxic of those tested.

9.19 HENDERSON, I. F. (1969) A laboratory method for assessing the toxicity of stomach poisons to slugs. *Ann. appl. Biol.* **63**, 161–171.

A method is described that allows the toxicity of stomach poisons to the grey field slug, *Agriolimax reticulatus* (Muller), to be measured in the laboratory. The relative toxicities of three commonly used molluscicides, as expressed by the median lethal dose values, were: sodium pentachlorophenate most toxic with a median value of 22·9 $\pm$ 2·5 μg/slug, metaldehyde next with one of 85·2 $\pm$ 4·0 μg/slug and copper sulphate least toxic with one of 129·2 $\pm$ 5·9 to 131·6 $\pm$ 5·6 μg/slug. The technique allows a given dose of any poison, however repellent, to be administered, but does not measure the repellency or attractiveness.

9.20 LORD, K. A. (1968) Studies on the penetration and sorption of insecticides in insects. *S.C.I. Monogr.* No. 29, 35–46.

Recent studies on the resistance of a diazinon-selected strain of houseflies to diazinon and DDT show that these penetrate more slowly into this strain than



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into susceptible flies. In both strains the rate of entry of poison into flies increases with the applied dose, but the proportion of the dose that penetrates decreases. The relationship between the dose applied and the amount entering houseflies differs for the two strains. To some extent the widely differing doses of poison needed to kill insects dosed by different methods may be explained by the greater proportion of a dose that penetrates the cuticle from a smaller dose.

Differences in the rate of penetration of an insecticide through insect cuticle by itself would be expected only to affect how quickly a lethal amount of poison accumulated at the site of action. However, slow penetration may be expected to increase the effect of metabolism and excretion of poison by allowing more time for loss of poison, and thereby increasing the dose needed to be applied to the outside of the insect.

When distribution of diazinon and its metabolites in flies was being examined, anomalous results suggested that the insecticide was sorbed by parts of the insect body. Tests with ground up parts of flies showed that the solids take up diazinon and diazoxon from aqueous solution. The insecticides are sorbed by various parts of the housefly, and the integument seems to be particularly active. Because insecticide is sorbed at sites other than those at which it acts, it is likely that the amount of poison needed to kill an insect is increased by sorption away from the site of action.

Sorption is reversible and the distribution coefficient between fly solids and water is largely independent of the concentration of diazinon and diazoxon. At least part of the sorption process seems to be associated with the lipids of the fly, because sorption is diminished by extraction of the tissues with fat solvents and the substances extracted by the solvents sorb diazinon.

9.21 LORD, K. A., MAY, M. A. & STEVENSON, J. H. (1968) The secretion of the systemic insecticides dimethoate and phorate into nectar. *Ann. appl. Biol.* **61**, 19–27.

Dimethoate and phorate were applied to soil in pots growing fuchsia, nasturtium and bean. Twenty-five mg dimethoate applied to a 5-in. pot made nectar from fuchsia and nasturtium and nectaries of beans toxic to bees and *Drosophila melanogaster*. Similar amounts of phorate and disulfoton did not.

Gas chromatography showed that 4 days after treatment there was at least 100 times more dimethoate than phorate in the nectar of fuchsia and nasturtium.

The dimethoate in nectaries taken from bean plants treated with 0·5–50 mg dimethoate per pot was assayed by gas chromatography. The concentration of dimethoate in the nectaries depended on the applied dose: it was greatest 4 days after treatment. Loss was more rapid with larger than with smaller doses.

9·22 SAWICKI, R. M. & FARNHAM, A. W. (1967) Genetics of resistance to insecticides of the SKA strain of *Musca domestica*. II. Isolation of the dominant factors of resistance to diazinon. *Ent. exp. appl.* **10**, 363–376.

The dominant factors for resistance to diazinon, i.e. R3 on the III linkage group, and gene *a* for low ali-esterase on V linkage group were isolated in the homozygous condition from the single mutant progenies of a cross between diazinon-resistant SKA flies, and a susceptible strain marked with the recessive mutants, *ocra* (III linkage group) and *ar* (V linkage group). Each of the two incompletely dominant factors when homozygous conferred a similar but small resistance to diazinon (R.F. 13–34) and very little resistance to diazoxon (R.F. 3–5) and differed in their response to diazinon in the presence of sesamex. Sesamex synergised diazinon very much against flies with R3 only, but increased resistance to diazinon by ×2 in flies with gene *a* only. *n*-Propyl paraoxon was almost



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equally effective as a synergist with diazinon against susceptible flies, and strains with R3 or gene *a* only (S.F. 1·4–3·6).

A third factor segregates independently of the other two factors and confers very slight resistance to diazinon (*c.* ×3).

9.23 SAWICKI, R. M. & FARNHAM, A. W. (1968) Genetics of resistance to insecticides of the SKA strain of *Musca domestica*. III. Location and isolation of the factors of resistance to dieldrin. *Ent. exp. appl.* **11**, 133–142.

SKA flies have two factors of resistance to dieldrin: the major factor DR4, on the IV linkage group, is intermediate and confers immunity to topically applied dieldrin in acetone during the first 24 hours, but increasing numbers of deaths during the next 72 hours decrease resistance to *ca.* ×700. The proportion of SKA flies with this factor has decreased over the last three years from *ca.* 25% to fewer than 10%.

The minor factor of resistance R2, on the II linkage group, greatly delays knock-down by retarding the penetration of dieldrin, but gives ×2 resistance at death. This factor is intermediate and is probably identical to the one in SKA flies that also delays penetration and knock-down by diazinon, DDT and other insecticides, and is retained in the SKA flies by selection with diazinon.

The presence of DR4 in SKA flies is probably not the result of selection with diazinon. It has almost certainly been inherited from the chlordane-resistant parents of the SKA strain.

9.24 STEVENSON, J. H. (1968) Laboratory studies on the acute contact and oral toxicities of insecticides to honeybees. *Ann. appl. Biol.* **61**, 467–472.

Standard procedures for determining acute oral and contact toxicities of insecticides to worker honeybees were developed and used to find the median lethal doses (LD50) of twenty-one compounds. The test procedures can be simplified to give less precise results and can be applied with little modification to other species of bee.

9.25 WAY, M. J. & BANKS, C. J. (1968) Population studies on the active stages of the black bean aphid, *Aphis fabae* Scop., on its winter host *Euonymus europaeus* L. *Ann. appl. Biol.* **62**, 177–197.

Autumn populations of *Aphis fabae* Scop. on the primary host *Euonymus europaeus* L. were little affected by natural enemies, most of which had begun to hibernate before the aphid population developed.

The size of the population in spring was usually determined by the number of overwintering eggs on a bush. The fundatrices hatched about 3–6 weeks before natural enemies became common. The growth of large *A. fabae* populations was first halted by the effects of intra-specific competition, notably by the production and departure of emigrant alatae and by adult apterae reproducing more slowly. Later, natural enemies, especially *Adalia 2-punctata* (L.), Syrphidae and the parasite *Trioxys* sp. (near *angelicae*), multiplied and accelerated the decline in the aphid populations, which usually disappeared in June leaving many immature natural enemies. Larval *A. 2-punctata* began to eat parasitised aphids and cannibalised other larvae and pupae.

The small populations of *A. fabae* that develop from few overwintering eggs are at greater risk from natural enemies than are large ones. Intraspecific competition still slowed population increase, because most aphids remained crowded on the few originally colonised twigs. Such populations produced very few emigrant alatae before they were exterminated by the combination of *T. angelicae* with specific and non-specific predators. Adult Cantharidae killed many of the aphids, especially in hedgerows, where they were abundant.



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Coccinellidae, Anthocoridae and syrphid larvae, and the adults of non-specific predators, notably Cantharidae, prevented recolonisation of *E. europaeus* throughout July and August. Leaves of *E. europaeus* may remain physiologically suitable for *A. fabae* throughout July but begin to deteriorate in August when *A. fabae* kept on them becomes less fecund.

Experiments using exclusion techniques provided evidence that natural enemies that attack *A. fabae* on *E. europaeus* and on summer hosts cause the common 2-year cycle of aphid abundance.

Individual *E. europaeus* differ consistently in the extent to which they are colonised by *A. fabae*. Conditions are discussed that should govern the choice of *E. europaeus* bushes on which the *A. fabae* populations can be used as sensitive indicators of later crop infestations.

## Entomology Department

### Book

10.1 Johnson, C. G. (1969) *Migration and dispersal of insects by flight.* London: Methuen, *c.* 750 pp.

### Theses

10.2 Shaw, M. J. P. (1968) Polymorphism in relation to migration by alate alienicolae of *Aphis fabae* Scopoli. Ph.D. Thesis, University of London.

10.3 Taylor, W. C. E. (1968) The effects of leaf-eating insects, especially *Plutella maculipennis* Curtis and *Phaedon cochleariae* F. on the growth and yield of some cruciferous plants. Ph.D. Thesis, University of London.

10.4 Thompson, A. R. (1968) The loss of chlorfenvinphos from soil by leaching and the effects of chlorfenvinphos on soil invertebrates. Ph.D. Thesis, University of London.

### General Papers

10.5 Edwards, C. A. (1969) Soil pollutants and soil animals. *Scient. Am.* April, 88–89.

10.6 Edwards, C. A. & (Reichle, D. E.) (1969) The role of soil invertebrates in turnover of organic matter and nutrients. In: *Analysis of temperate forest ecosystems.* Heidelberg and New York: Springer-Verlag. (In the press.)

10.7 Johnson, C. G. (1968) A continuous census of airborne insect pests in Europe. *EPPO 7th Session, Paris, 1967.*

10.8 Johnson, C. G. (1968) Frank Raw 1920–1967. *Pedobiologia* **8**, 134.

10.9 Johnson, C. G. (1968) Professor Frank Raw. *Nature, Lond.* **217**, 691.

10.10 Lewis, T. (1968) Windbreaks, shelter and insect distribution. *Span* **11**, 186–189.

10.11 Lewis, T. (1969) Factors affecting primary patterns of infestation. *Ann. appl. Biol.* **63**, 315–317.

10.12 Stephenson, J. W. (1968) A review of the biology and ecology of slugs of agricultural importance. *Proc. malac. Soc. Lond.* **38**, 169–177.



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10.13 TAYLOR, L. R. (1968) The Rothamsted Insect Survey. *Nat. Sci. Schools* **6** (1), 2–9.

RESEARCH PAPERS

10.14 BARDNER, R., LOFTY, J. R., (MASKELL, F. E.) & HUSTON, P. (1968) Movement and oviposition of wheat-bulb flies. *Pl. Path.* **17**, 97–103.

Water traps examined weekly were used to assess the activity of adult Wheat Bulb flies during the oviposition period in late July, August and early September. Traps were placed at various distances up to one mile (1·6 km) from known sources of infestation at Whittlesey, Cambridgeshire and at Rothamsted. Most flies were caught down wind from possible emergence sites and few were caught more than $\frac{1}{4}$–$\frac{1}{2}$ mile (0·4–0·8 km) away. The distribution of flies between traps was similar in both the first and second halves of the trapping period. At Whittlesey there was a significant positive correlation between the number of flies caught in a trap and the number of eggs laid in the field containing the trap.

10.15 (BERRY, R. E.) & TAYLOR, L. R. (1968) High altitude migration of aphids in maritime and continental climates. *J. Anim. Ecol.* **37**, 713–722.

Aphids were sampled at 2000 ft (610 m) above ground over eastern Kansas, U.S.A. and 1000 ft (305 m) above ground over southern England in summer. Afternoon aerial densities were greater over southern England, but night-time densities much less than over Kansas. A significantly larger proportion remained aloft overnight over eastern Kansas than over southern England and the difference is not attributable to sampling artifacts. Night air temperatures were predominantly above the flight threshold over eastern Kansas and below it over southern England. The low-level jet stream over eastern Kansas may be transporting actively flying aphids, but it was not responsible for the large overnight densities.

10.16 CALAM, D. H. & YOUDEOWEI, A. (1968) Identification and functions of secretions from the posterior scent gland of fifth instar larvae of the bug *Dysdercus intermedius*. *J. Insect Physiol.* **14**, 1147–1158.
(For summary see No. 9.12.)

10.17 EDWARDS, C. A. (1968) Changes in soil faunal populations caused by aldrin and DDT. *Trans. 8th int. Congr. Soil Sci., Bucharest, 1964* **3**, 879–886.

DDT and aldrin were applied to various agricultural soils in two large replicated experiments and five smaller ones. Two-inch diameter soil samples were taken at two-monthly intervals, and the animals extracted by flotation or Tullgren funnels. The insecticide residues were estimated from smaller soil samples using gas liquid partition chromatography. About 10% of DDT disappeared annually; aldrin disappeared faster but about half the amount that disappeared was converted into dieldrin.

Aldrin did not affect predatory mites, nematodes, earthworms or enchytraeid worms, but killed other mites, Collembola, pauropods, root aphids and dipterous and coleopterous larvae. DDT readily killed predatory mites; this increased numbers of Collembola which are relatively resistant to DDT. Otherwise DDT had less effect on most groups of soil animals than aldrin.

10.18 EDWARDS, C. A. & FLETCHER, K. E. (1969) Terrestrial arthropod populations. In: *Methods for the study of production and energy flow in soil ecosystems*. IBP Handbook. Ed. J. Phillipson. Oxford: Blackwells Scientific Publications. (In the press.)



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10.19 EDWARDS, C. A. & FLETCHER, K. E. (1969) The assessment of terrestrial invertebrate populations. *Joint UNESCO/IBP Symposium on methods of study in soil ecology. Paris, 1967.* (In the press.)

Questionnaires sent to 150 soil zoologists showed that 74% used some form of Tullgren funnel for extracting animals from soil samples. Samples from small areas of arable, pasture and woodland, all on the same clay loam soil, were extracted simultaneously to compare the efficiency of seven dynamic and four mechanical extraction methods in common use. Extractions with funnels and with the Salt & Hollick flotation method were compared for peat, clay, clay loam, silt clay loam and sandy soils. Macfadyen high gradient air-conditioned funnels extracted micro- and meso-arthropods most efficiently from most types of soil but especially from woodland soils. Both mechanical and flotation methods were reasonably efficient in extracting macroarthropods. Mechanical methods were essential for eggs, pupae and cocoons, and preferable to dynamic methods for onychiurid Collembola. Funnel extraction was improved by inverting the intact soil samples on to the sieves and using picric acid or 70% ethyl alcohol with 5% glycerol as a collecting fluid. In general, flotation methods are most appropriate for sandy arable soils but useless for peat or soils with much organic matter. Soil samples could be stored for up to a month at 5° C without serious changes in numbers of animals.

10.20 EDWARDS, C. A. & LOFTY, J. R. (1969) The influence of agricultural practice on soil micro-arthropod populations. In: *The soil ecosystem.* Ed. J. G. Sheals & P. W. Murphy. (*Publ. Systematics Ass.* No 8.) (In the press.)

Cultivation decreased the number of species of arthropods in soil and the numbers of Collembola, Pauropoda and oribatid mites (Cryptostigmata, Acarina). It only slightly affected numbers of other Acarina, Symphyla, Diplopoda and Protura. Species with a short life cycle repopulated cultivated soil within a single growing season. Some insects were much fewer in cultivated land than in pasture or woodland. When old grass was ploughed numbers of wireworms diminished but recovered in three years when the land was reseeded with grass; by contrast, when planted to lucerne they continued to diminish.

Organic manure greatly increased numbers of Collembola and Acarina and inorganic fertilisers caused small increases. Changing the pH of the soil from acid to basic increased numbers of micro-arthropods. Irrigation increased numbers of some species of micro-arthropods but decreased others.

Pesticides greatly changed the numbers and diversity of species of micro-arthropods in soil. Some species increased greatly, especially after treatment with organophosphate insecticides, because their principal predators were killed.

10.21 FRENCH, R. A. (1969) Migration records, 1966. *Entomologist.* (In the press.)

10.22 FRENCH, R. A. & (HURST, G. W.) (1969) Moth immigration in the British Isles in July, 1968. *Entomologist's Gaz.* **20**, 37–44.

At least five species of moths arrived in the British Isles on the night of 30 June/1 July 1968 at the same time as dust that originated in the Sahara. These two events were coincidental and not connected, although both the insects and the dust were wind-borne. The origin of the insects was either N.W. Africa or N.W. Spain.

10.23 (GOULD, G. E.) & EDWARDS, C. A. (1968) Damage to field corn by symphylans. *Proc. Indiana Acad. Sci.* for 1967, **77**, 214–221.

Several fields in Indiana were extensively damaged by symphylans of several



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species in 1966 and 1967. These animals have not been previously recorded as pests of corn in Indiana and other mid-western states. They may have been recently introduced and reports of damage to corn are increasing. Experiments to find economic control of symphylans were inconclusive.

10.24 (HALGREN, L. A.) & TAYLOR, L. R. (1968) Factors affecting flight responses of alienicolae of *Aphis fabae* Scop. and *Schizaphis graminum* Rondani (Homoptera; Aphididae). *J. Anim. Ecol.* **37**, 583–593.

Effects of temperature, light, age, starvation and distance fallen on the flight response of alienicolae of *Aphis fabae* and *Schizaphis graminum* were measured. Optimal flight response was elicited in *Aphis fabae* at temperatures from 20 to 30° C and 35 to 40° C, and in *Schizaphis graminum* from 20 to 40° C; inhibition occurred in both species below 15° C. The response declined as the light intensity decreased below 2000 ft-candles (21520 m-candles). Both species responded to low light intensity early in their flying life. In ideal conditions the response of both species declined with age, to 5% in about nine days in *Aphis fabae* and three days in *Schizaphis graminum*. When starved, 5% of *Aphis fabae* responded after four days and 5% of *Schizaphis graminum* after two days. Increasing the falling distance beyond *c.* 1 m produced no significant change in effect in either species.

10.25 HEATHCOTE, G. D., PALMER, J. M. P. & TAYLOR, L. R. (1969) Sampling for aphids by traps and by crop inspection. *Ann. appl. Biol.* **63**, 155–166.

The catches of 30 aphid genera and species during three years in a suction trap at 40 ft and on a yellow cylindrical sticky trap at 5 ft at Rothamsted and at Broom's Barn are tabulated.

The catches show the differential attraction to yellow of different species, the effects of local vegetation and the seasonal distribution of aphids that are crop pests or potential vectors of viruses.

Suction-trap catches were the more consistent but both traps were more effective at recording the first seasonal immigration of *Myzus persicae* Sulz. and *Aphis fabae* Scop. than the British Sugar Corporation crop-inspection scheme.

10.26 HENDERSON, I. F. (1968) Laboratory methods for assessing the toxicity of contact poisons to slugs. *Ann. appl. Biol.* **62**, 363–369.
(For summary see No. 9.18.)

10.27 HENDERSON, I. F. (1969) A laboratory method for assessing the toxicity of stomach poisons to slugs. *Ann. appl. Biol.* **63**, 167–171.
(For summary see No. 9.19.)

10.28 JONES, M. G. (1968) The effect of moving carabids on oviposition by frit fly (*Oscinella frit* L.). *Entomologist's mon. Mag.* **104**, 85–87.

Active carabids running through the oat crop disturb the ovipositing female frit fly which flies off without laying all her ripe eggs in one place. A similar effect is produced by beads or dead beetles moved mechanically.

10.29 JONES, M. G. (1968) Observations on hymenopterous parasites of frit fly *Oscinella frit* L. on oats. *J. appl. Ecol.* **5**, 445–450.

The periods when most of the hymenopterous parasites emerge from the tiller generation of frit flies coincide with the flight of flies from the panicles, that is to say they are too late to attack their immature stages. The three chalcid species *H. circula*, *C. vulgaris* and *C. bicolor* emerge from the tiller generation during



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July and are the only species able to parasitise the immature stages of frit flies in the grains. Very few of the panicle generation of frit flies were parasitised: frit flies in Britain have a generation out of phase with the life histories of the parasites.

10.30 JUDENKO, E. (1969) An experiment to assess losses caused by frit-fly (*Oscinella frit* L.) shoot attack and the application of phorate in a crop of sweet corn (*Zea mays* L.). *PANS.* **15**, 47–53.

Seven kinds of yield of sweet corn were examined. On plots not treated with phorate, frit-fly lessened all seven kinds of yield, six significantly.

Phorate (1·5 lb a.i./acre) applied as granules in the seed furrows at planting significantly lessened shoot attack by frit-fly and lessened losses in five kinds of yield significantly. Despite lessening the losses caused by frit-fly, phorate did not increase actual yields. The benefits from control of frit-fly seemed to be nullified by an adverse effect of phorate on plants. Difference between the yields from treated and untreated areas were therefore not a measure of the losses caused by the pest against which phorate was aimed.

10.31 TAYLOR, W. E. & BARDNER, R. (1968) Effects of feeding by larvae of *Phaedon cochleariae* (Fab.) (Coleoptera; Chrysomelidae) and *Plutella maculipennis* (Curtis) (Lepidoptera; Plutellidae) on the yield of radish and turnip plants. *Ann. appl. Biol.* **62**, 249–254.

Different numbers of larvae of the beetle *Phaedon cochleariae* (F.) and the moth *Plutella maculipennis* (Curt.) were fed on the leaves of turnip plants (var. Early Milan White) and radish (var. French Breakfast) growing in a constant-environment room.

Turnips grew more slowly than radish, were less affected by insect feeding and were affected more by *Phaedon* than by *Plutella*. *Phaedon* larvae severed leaf veins and rasped the leaf surface, thus killing more leaf tissue by desiccation than they ate. They remained on and greatly damaged the older leaves and their feeding lessened yield. *Plutella* larvae fed on leaves of all ages, which they ate cleanly, leaving the veins. They pupated sooner than *Phaedon* and did less damage to older leaves, which grew larger and lived longer than corresponding leaves on intact plants. This compensatory growth by turnip prevented loss of yield and may have increased it, as indicated by dry weight of the roots.

Both species of insect decreased the yield of radish similarly. Loss of yield of turnip caused by *Phaedon* or of radish caused by both species of insect was negatively and linearly proportional to the number of larvae that fed on the leaves.

10.32 TAYLOR, W. E. & BARDNER, R. (1968) Leaf injury and food consumption by larvae of *Phaedon cochleariae* (Fab.) (Coleoptera; Chrysomelidae) and *Plutella maculipennis* (Curtis) (Lepidoptera; Plutellidae) feeding on turnip and radish. *Entomologia exp. appl.* **11**, 177–184.

Larvae of *Plutella maculipennis* (Lepidoptera; Plutellidae) and *Phaedon cochleariae* (Coleoptera; Chrysomelidae) were fed on the leaves of both turnip *Brassicae rapa* and radish *Raphanus sativus*. Both the weight of the food eaten and the area of leaf injured were measured. The weight eaten depended on the nutritive value of the food, whereas the area of leaf injured depended on the leaf thickness and the method of feeding of the insect. Both species developed fastest on young plants, which contained the most protein. They ate a greater weight of old than of young leaves, and injured a greater area of radish than of turnip leaf, which had more dry matter/unit area. The area of leaf injured by *P. maculipennis*



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was equivalent to the weight eaten, but *P. cochleariae*, which had a different method of feeding, destroyed much more leaf area than was expected from the weight of food eaten.

10.33 YOUDEOWEI, A. (1968) The behaviour of a cotton stainer, *Dysdercus intermedius*, Distant (Heteroptera, Pyrrhocoridae) towards models and its significance for aggregation. *J. Anim. Behav.* (In the press.)

Observations were made on the behaviour of individual 5th instar larvae of *D. intermedius* towards different kinds of decoys, namely; clay models similar in size, shape and colour to 5th instar larvae; clay rolls painted red and similar in size to 5th instar larvae but not contoured; frozen 5th instar larvae; live tethered 5th instar larvae; and freshly killed 5th instar larvae. The frequency of peering, number of approaches, touches, probes and the time (seconds) spent in contact with each of the decoys were recorded. The insects did not discriminate in their approaches to decoys but preferred 'stainers' and 'stainer-like' shapes by peering, touching and probing more on the frozen, dead, live tethered insects and clay models than on the clay rolls. Also more time was spent in contact with these decoys than with the clay rolls. The insects made antennal signals to each other and this was at least partly responsible for intra-specific recognition which led to aggregation.

## Bee Department

### GENERAL PAPERS

11.1 BAILEY, L. (1968) Honey bee pathology. *A. Rev. Ent.* **13**, 191–212.

11.2 FREE, J. B. (1967) Recent discoveries about honey-bee behaviour that have possible applications to beekeeping. *Am. Bee J.* **107**, 448–450; (1968) *Apiacta* **1**, 1–5.

11.3 FREE, J. B. (1968) Studies on the seasonal changes in the activities of honey-bee colonies. *Rep. Cent. Ass. Br. Beekeep. Ass.*, pp. 1–12.

11.4 SIMPSON, J. (1968) Le microclimat à l'interieur de la grappe d'abeilles. In: *Traité de biologie de l'abeille*. Ed. R. Chauvin. Paris: Masson, Vol. **1**, 224–234.

11.5 SIMPSON, J. (1968) L'essaimage. In: *Traité de biologie de l'abeille*. Ed. R. Chauvin. Paris: Masson, Vol. **2**, pp. 32–44.

### RESEARCH PAPERS

11.6 BAILEY, L. (1967) Acute bee-paralysis virus in adult honey bees injected with sacbrood virus. *Virology* **33**, 368.

Injecting adult bees with sacbrood virus caused acute bee-paralysis virus to multiply. Infectivity tests failed to show that sacbrood virus had multiplied. Queen bees injected with sacbrood virus produced apparently healthy offspring.

11.7 BAILEY, L. (1967) *Nosema apis* and dysentery of the honeybee. *J. apicult. Res.* **6**, 121–125.

Severe winter losses of honeybee colonies and poor growth or dwindling in spring were associated with dysentery. They were not caused simply by an enzootic infection with *Nosema apis*. Infection, although it is common, is usually slight in most colonies, and is spread by dysentery, but it is not the primary cause.



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11.8 BAILEY, L. (1967) The world distribution of viruses of the honey bee. *Bull. apicole*. **10**, 121–124.

Chronic Bee-Paralysis Virus (CBPV), Acute Bee-Paralysis Virus (ABPV) and Sacbrood Virus (SBV) are common in apparently healthy colonies. CBPV causes paralysis in nature and has been found in sick bees from many parts of the world. SBV is similarly widespread; ABPV probably is too, but it has not been associated with any disease in nature. The factors that cause CBPV and SVB to spread within colonies and cause severe disease are unknown.

11.9 BAILEY, L., GIBBS, A. J. & WOODS, R. D. (1968) The purification and properties of chronic bee-paralysis virus. *J. gen. Virology* **2**, 251–260.

Purified preparations of chronic bee-paralysis virus were obtained by clarifying water extracts of paralysed bees with ether and carbon tetrachloride; the virus particles were concentrated from the clarified extracts either by centrifugation or precipitation with ammonium sulphate. The preparations contained particles of three sizes, all approximately 220 Å wide and ellipsoidal in outline, but about 410, 540 or 640 Å long with sedimentation coefficients ($S_{20,w}$) of 97, 110 and 125 respectively. The shortest particles contained least nucleic acid, and preparations containing mostly short particles were less infective than those containing mostly long ones. The particles contained ribose nucleic acid with a molar base ratio of G 20%–A 24%–C 28%–U 28%. When incubated in cold acid or alkali solutions (1N), the virus particles formed empty rounded protein shells.

11.10 BAILEY, L. & MILNE, R. G. (1969) The multiplication regions and interaction of acute and chronic bee-paralysis viruses in adult honey bees. *J. gen. Virol.* **4**, 9–14.

Serological and infectivity tests showed that acute bee-paralysis virus accumulated in the heads of acutely paralysed bees, especially in the hypopharyngeal glands, and that much virus also occurred in the brain, where particles resembling acute bee-paralysis virus were made visible by electron microscopy. Similar tests showed that chronic bee-paralysis virus was concentrated in the brains of chronically paralysed bees. Electron microscopy of the brains showed particles resembling chronic bee-paralysis virus, but these may have been synaptic vesicles or sectioned microtubules, since similar particles were also seen in the brains of apparently healthy bees. These particles also resembled particles that were seen in sections of pellets of purified chronic bee-paralysis virus, and that were electron-transparent in the centre.

Many bees injected with acute bee-paralysis virus and kept at 35° C remained apparently healthy though they contained at least as much virus as bees injected with acute bee-paralysis virus and kept at 30°C, all of which died of acute paralysis. Conversely, chronic bee-paralysis virus multiplied more at 30° than at 35° C, though it killed bees more slowly at the lower temperature. When acute bee-paralysis virus and chronic bee-paralysis virus were injected together into single bees, acute bee-paralysis virus multiplication was depressed at 35° C and chronic bee-paralysis virus multiplication was depressed at 30° C.

11.11 (BURGES, H. D.) & BAILEY, L. (1968) Control of the Greater and Lesser Wax moths (*Galleria mellonella* and *Achroia grisella*) with *Bacillus thuringiensis*. *J. Invert. Path.* **11**, 184–195.

A commercial formulation of *Bacillus thuringiensis* incorporated into cold bees-wax and hence into bee combs, controlled the wax moths, *Galleria mellonella* and *Achroia grisella*, without harming bees. Treated combs used continuously by bees remained resistant to *G. mellonella* after two seasons. In laboratory tests with *G. mellonella* the $LD_{50}$ of commercial preparations of *B. thuringiensis*,



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serotypes I or V, was $4{\cdot}1 \times 10^{-3}$ to $1{\cdot}1 \times 10^{-2}$ % dry W/W in brood comb ($=1{\cdot}23 \times 10^{6}$ to $3{\cdot}5 \times 10^{6}$ live spores/g of brood comb). The values for *A. grisella* were larger. Tests with purified spores and endotoxin-crystal enriched preparations showed that the crystal was the most important lethal factor for *G. mellonella*. Heat decreased the number of spores germinating in agar and also the effect of crystals against wax moths at similar rates, crystals becoming almost ineffective after 30 minutes at 95° C. It is not practicable, therefore, to add *B. thuringiensis* while the wax is molten during the manufacture of comb foundation.

11.12 BUTLER, C. G. & CALAM, D. H. (1969) Pheromones of the honey bee—the secretion of the Nassanoff gland of the worker. *J. Insect Physiol.* **15**, 237–244.

Gas chromatographic analysis of the secretion of the Nassanoff gland of worker honeybees within four minutes of its collection indicates the presence of both isomers of citral to the combined extent of about 3% of the amount of geraniol present. Field tests show that citral is the most attractive single compound in the secretion to honeybees. It is more attractive when tested alone (0·39 μg) against a combination of the other known components of the secretion (geraniol, 100 μg, with geranic and nerolic acids, 100 μg). Citral (0·77 μg) + geraniol (0·20–0·39 μg) was almost as attractive to bees as the odour of Nassanoff secretion collected from ten foraging bees.

11.13 BUTLER, C. G. & CALLOW, R. K. (1968) Pheromones of the honeybee (*Apis mellifera* L.): the 'inhibitory scent' of the queen. *Proc. R. ent. Soc. Lond.* (*B*). **43**, 62–65.

The queen's 'inhibitory scent', which acts additionally to the contact effect of 9-oxodec-2-enoic acid in inhibiting queen rearing and development of workers' ovaries, is identified as the odour of 9-hydroxydec-2-enoic acid which, like 9-oxodecenoic acid, is produced in the queen's mandibular glands.

11.14 FREE, J. B. (1968) The behaviour of bees visiting runner beans (*Phaseolus multiflorus*). *J. appl. Ecol.* **5**, 631–638.

*Bombus agrorum* foragers entered the mouths of runner-bean flowers and collected nectar only or nectar and pollen: some kept constant to one or other occupation. Most *B. lucorum* and *B. terrestris* foragers obtained nectar through holes they bit in the bases of the corolla tubes. Most honeybees collected nectar either by entering the flowers, or by robbing nectar through holes bitten by *B. lucorum* and *B. terrestris*; very few honeybees collected pollen. The number of honeybees robbing the flowers depended on the number of *B. lucorum* and *B. terrestris* present. Nectar-gathering honeybees readily changed from robbing to collecting nectar *via* the mouths of the flowers and *vice versa*. The numbers of bumblebees and honeybees gathering pollen were greatest between 08.00 and 10.00 hours and the numbers robbing were greatest during the late afternoon. Bumblebees worked faster and visited more flowers per plant than honeybees and probably their foraging areas on a single trip were no greater than those of honeybees. However, their foraging areas during several trips taken together were larger.

11.15 FREE, J. B. (1968) Dandelion as a competitor to fruit trees for bee visits. *J. appl. Ecol.* **5**, 169–178.

Honeybee colonies in fruit orchards often collected much dandelion pollen. Bees visiting dandelion become conditioned to it and, even when the dandelion flowers closed at midday or early afternoon, only a small percentage of bees changed to



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fruit. Elimination of dandelions from orchards should increase the pollinating efficiency of the honeybee colonies present. When dandelion pollen was plentiful nectar-gathering bees became dusted with it, but most of them combed it from their bodies and discarded it.

11.16 FREE, J. B. (1968) The foraging behaviour of honeybees (*Apis mellifera*) and bumblebees (*Bombus* spp.) on blackcurrant (*Ribes nigrum*), raspberry (*Rubus idaeus*) and strawberry (*Fragaria* × *Ananassa*) flowers. *J. appl. Ecol.* **5**, 157–168.

Observations on the behaviour of bees visiting blackcurrant, raspberry and strawberry flowers showed that bees touched both stamens and stigmas of nearly every flower visited and so could have pollinated them. Queen bumblebees were more abundant than honeybees on blackcurrants, particularly in cool weather. They worked faster and visited more flowers per bush and per trip than honeybees, but, like honeybees, tended to keep to one row per trip. The honeybee population fluctuated more than the bumblebee and reached a peak at about midday. Few honeybees collected blackcurrant pollen, even when their colonies were in blackcurrant plantations. Honeybees were more numerous than bumblebees on raspberries and their numbers fluctuated more. Bees collecting nectar from raspberry flowers acquired pollen incidentally; more than half of them packed it into their corbiculae and the others discarded it. Individual bees tended to be consistent, from day to day, in collecting nectar only or pollen. Bees that collected nectar only spent less time per flower than those that collected pollen. Colonies collected a greater percentage of raspberry pollen near the beginning and end of foraging for the day than during the time of maximum foraging, and the number of bees visiting raspberry increased towards late afternoon. Very few bumblebees visited strawberries. In addition to collecting nectar, and sometimes collecting pollen incidentally, some bees collected pollen deliberately by scrabbling over the anthers, and bees that collected pollen worked faster than those that did not. A bee worked only a small percentage of the open flowers on each plant it visited; nectar-gatherers worked fewer flowers per plant than pollen-gatherers. Honeybee activity increased, in general, with temperature; the number of bees on the crop reached a peak in early afternoon, and the numbers of pollen-gatherers and the amounts of pollen collected were greatest near midday.

11.17 FREE, J. B. (1968) The pollination of blackcurrants. *J. hort. Sci.* **43**, 69–73.

Observations failed to show that cross-pollination between different varieties of blackcurrants increased fruit set in field crops.

11.18 FREE, J. B. (1968) The pollination of strawberries by honey-bees. *J. hort. Sci.* **43**, 107–111.

Honeybees increased the percentage of flowers that set fruit, the mean weight per berry and the percentage of well-formed berries.

11.19 FREE, J. B. & NUTTALL, P. M. (1968) Effect of the time of day at which honeybee colonies are first allowed flight in a new location on their choice of flower species. *Nature, Lond.* **218**, 982.

Delaying the release of colonies taken to apple orchards until dandelion had ceased to yield for the day, increased the proportion of bees foraging on the apple flowers.



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11.20 FREE, J. B. & NUTTALL, P. M. (1968) The pollination of oilseed rape (*Brassica napus*) and the behaviour of bees on the crop. *J. agric. Sci., Camb.* **71**, 91–94.

In spite of the entomophilic structure of the rape flower, which is very attractive to nectar- and pollen-gathering bees, the crop yields well without insect pollination.

11.21 FREE, J. B. & RACEY, P. A. (1968) The effect of the size of honeybee colonies on food consumption, brood rearing and the longevity of the bees during winter. *Ent. exp. & appl.* **11**, 241–249.

Near Harpenden, Hertfordshire, brood rearing continued later into the autumn in small than in large colonies, and in colonies headed by queens of the current year than by queens of the previous year. In spring the amount of brood present increased with colony size, but there was more brood per bee in small than in large colonies. Food consumption per bee during winter decreased with increase in colony size, especially in colonies with fewer than 18000 bees. The size of a colony in spring was related directly to its size in the previous autumn, and the proportion of bees that survived the winter was similar in large and small colonies.

11.22 FREE, J. B. & SIMPSON, J. (1968) The alerting pheromones of the honeybee. *Z. vergl. Physiol.* **61**, 361–365.

When honeybees sting an object they release pheromones that direct the attacks of other bees towards it. 2-Heptanone is the principal aggression-provoking component in the secretion of the mandibular gland. Isoamyl acetate is not the only active component of the aggression-provoking secretion at the base of the sting but no such component occurs in the venom itself.

11.23 SIMPSON, J., RIEDEL, I. B. M. & WILDING, N. (1968) Invertase in the hypopharyngeal glands of the honeybee. *J. apicult. Res.* **7**, 29–36.

The transition from 'summer' bees, in which the hypopharyngeal glands change rapidly in size and invertase content as a bee gets older, to 'winter' bees, which at all ages have large glands rich in invertase, progressed gradually towards the end of the summer. In summer, glands of many foraging bees were large, and in winter those of bees feeding brood contained much invertase. The visible secretion masses in the glands are probably larval food. The invertase-containing secretion was not separately visible. It could be either scanty or abundant in large visibly active glands; it was always abundant in glands that appeared to be almost completely atrophied. The latter must actively secrete invertase, since they discharged more than could have come from reserves within them.

## Statistics Department

### BOOK

12.1 (DOUGLAS, J. W. B., ROSS, J. M.) & SIMPSON, H. R. (1968) *All our future*. London: Peter Davies, xiv, 241 pp.

### RESEARCH PAPERS

12.2 CHURCH, B. M. (1968) Fertiliser use on cereals in England and Wales, 1966. *Ceres* (*Journal of the Home-Grown Cereals Authority*) **3**, 7–14.

Information is given on the manuring of cereal crops obtained from surveys of 31 districts of England and Wales during 1966. Almost all cereals had some N, and average dressings on fields receiving nutrients were about 70 units N, 40 units



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$P_2O_5$ and 40 units $K_2O$ for winter cereals, and 60 units N, 35 units $P_2O_5$ and 35 units $K_2O$ for spring wheat and barley. The average use of N per acre of spring barley for a district increased with the percentage of the arable acreage under cereals. There are large differences in practice from farm to farm within districts. Less N is used per acre of spring barley on small than large farms, but factors such as type of rotation and type of farm account for only a small part of the local variations in practice.

Most of the winter wheat was top dressed in 1966; two thirds of the spring barley and rather less of the winter wheat was combine drilled. Average individual and total dressings were similar for crops that were combine-drilled and those with fertiliser broadcast in the seedbed. Top dressings to winter wheat were mostly in March–April, and to spring wheat in May; 5–10% of winter wheat had two top dressings.

12.3 CHURCH, B. M. (1969) Types of fertilisers used on farm crops in England and Wales, 1966. *N.A.A.S. q. Rev.* (In the press.)

A classification of fertilisers according to nutrient ratios is described, and estimates are given for regions based on major farming type of the relative use of different fertiliser types on individual crops. The main changes between 1962 and 1966 were increases in the use of high-N fertilisers on spring cereals and grassland, and on increase in the use of low-N fertilisers in the seedbed, followed by top dressings of 'straight' N, for winter cereals. High-K type ($1:1:1\frac{1}{2}$) fertilisers continued to predominate for potatoes. Liquid fertilisers were used on up to 5% of the treated acreage in eastern arable districts in 1966.

Average individual dressings of each fertiliser type are remarkably similar for spring and winter cereals, leys and permanent grass. Differences in average amounts of nutrients received by these crops are thus mainly accounted for by differences in the types of fertilisers used and the number of separate applications.

12.4 GOWER, J. C. (1968) Adding a point to vector diagrams in multivariate analysis. *Biometrika* **55**, 582–585.

A set of $n$ base points $P_i (i = 1, 2, \ldots, n)$, with known co-ordinates relative to orthogonal axes, and a further point $P_{n+1}$, with known distance from each of the base set are given. The co-ordinates of $P_{n+1}$ relative to the axes of the base set are found. The formula is especially simple when the base set is referred to its principal axes, for then the co-ordinates of $P_{n+1}$ for a subset of all the axes can be calculated from the co-ordinates of the $P_i$ in this subset only. The classical results for adding a point to a principal components or canonical variates analysis are obtained when the base set is derived using the appropriate distance functions. An example is given.

12.5 GOWER, J. C. (1968) Simulating multidimensional arrays in one dimension. *Jl R. statist. Soc. C.* **17**, 180–185.

In statistical operations on $n$-way tables (multidimensional arrays) the same algebraic operation is often repeated for each dimension, or for selected sets of dimensions. The multidimensional facilities built into algebraic autocode languages such as Algol, Fortran, PL/1 are not well-suited to this type of work, especially when the number of dimensions is variable, and it is better to treat all tables as 1-way arrays and to simulate by program the multidimensional aspects. This need not lead to inefficient computing because advantage can be taken of the usual reference to table-cells in some systematic order. A subroutine package of four algorithms (written in Algol) is given. These have been found useful for describing, and programming concisely, operations on multi-way tables. Facilities are provided for allowing the operations to extend over selected margins of the



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table, and the modifications for dealing with several differently classified tables are mentioned.

12.6 GOWER, J. C. (1969) The basis of numerical methods of classification. (In: *The soil ecosystem*. Ed. J. G. Sheals & P. W. Murphy. (*Publ. Systematics Ass.* No. 8.) (In the press.)

Here classification methods are themselves hierarchically classified. The main dichotomy is into methods that assign individuals to predetermined classes (identification), and methods that describe the inter-relationships between individuals, these being used as a basis for setting up classes (construction of classes). The descriptive methods are subdivided into hierarchic and multidimensional (ordination) methods, each of which is further divided into numerous other categories.

12.7 GOWER, J. C. & ROSS, G. J. S. (1969) Single linkage cluster analysis and minimum spanning trees. *J.R. statist. Soc. C.* **18**. (In the press.)

Minimum spanning trees (MST) and single linkage cluster analysis (SLCA) are explained, and it is shown that all the information required for the SLCA of a set of points is contained in their MST. Known algorithms for finding the MST are discussed. They are efficient even when there are very many points; this makes SLCA practicable when other methods of cluster analysis are not. Three relevant computing procedures are published in the Algorithm Section of the Journal (*see* ref. no. 12.13).

The use of the MST in the interpretation of vector diagrams arising in multivariate analysis is illustrated by an example.

12.8 HILLS, M. G. & (LITTLE, R. C.) (1969) The use of fertilisers on horticultural crops. *Exp. Hort.* No. 19, 16–22.

In addition to information on agricultural crops previously reported, estimates of fertiliser nutrient rates applied to horticultural crops (including hops and top fruit) were obtained from the 1966 Survey of Fertiliser Practice. These are compared with current standard recommended rates contained in *N.A.A.S. Advisory Paper* No. 4.

12.9 LEECH, F. B. & (KNOWLES, N. R.) (1969) An investigation on commercial farms of factors thought to contribute to egg cracking. *Brit. Poult. Sci.* **10**, 139–147.

An investigation of 52 egg production units showed that in battery units, but not other systems of husbandry, the proportion of defective eggs produced by birds in their second year was more than twice that of the first year. The proportion of defective eggs was unrelated to the shell thickness (measured by the deformation test on random samples of sound eggs from the same flocks). Damage to eggs during collection and packing was trivial relative to the proportions of defective eggs found in the nests or cages.

12.10 PREECE, D. A. (1969) Balanced $6 \times 6$ designs for nine treatments. *Sankhyā B.* (In the press.)

The row and column design

| | | | | | |
|---|---|---|---|---|---|
| 2 | 4 | 8 | 7 | 6 | 3 |
| 3 | 5 | 7 | 2 | 4 | 9 |
| 5 | 6 | 3 | 1 | 7 | 8 |
| 4 | 9 | 1 | 8 | 3 | 5 |
| 6 | 7 | 9 | 5 | 1 | 2 |
| 1 | 8 | 2 | 4 | 9 | 6 |



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published by Kshirsagar (*Calcutta statist. Ass. Bull.* (1957) **7**, 161–166) is balanced in the sense that the variance of an estimated treatment difference is independent of the treatments compared. With methods of classification similar to those used for Latin squares and Latin rectangles, the above design is shown to belong to a domain of 344 species grouped into 38 families.

12.11 PREECE, D. A. (1969) Balanced incomplete block designs with sets of identical blocks. *Technometrics.* (In the press.)

In his two monographs on the mathematics of experimental design, Professor S. Vajda (1967), when defining a balanced incomplete block design, imposed the restriction that no two blocks of the design may be identical. This restriction is foreign to the accepted definition, and has no relevance for experimental design. Several cyclic balanced incomplete block designs with sets of identical blocks, and for which $r$, $b$ and $\lambda$ have no common factor ($r \leqslant 20$), are given for the first time.

12.12 ROSS, G. J. S. (1968) Statistical models and designs for varietal, fertiliser and pesticide trials. *PANS* Section A **14**, 231–243.

The ideas underlying the common experimental designs are presented, rather than comprehensive instructions for layout and analysis. The emphasis is on estimation of effects rather than on significance testing.

12.13 ROSS, G. J. S. (1969) Minimum spanning tree. Printing the minimum spanning tree. Single linkage cluster analysis. *J.R. statist. Soc. C.* **18**. (In the press.)

Three algorithms, written in Algol, enable the minimum spanning tree to be computed from a given distance matrix, using Prim's method. The first computes the tree, the second is a useful method of printing the tree and the third uses the tree in a single linkage cluster analysis.

12.14 ROSS, G. J. S. (1969) Classification techniques for large sets of data. *Proc. St. Andrews' Colloquium in Numerical Taxonomy, 1968.* London: Academic Press. (In the press.)

The need for computer techniques able to classify hundreds or thousands of objects is stated. Existing techniques are described and it is shown that approximations involving much less computation may give adequate results.

12.15 WORKING PARTY ON STATISTICAL COMPUTING. (COOPER, B. E., CRADDOCK, J. M.), GOWER, J. C. (HARRISON, P. J., HILL, I. D.) & NELDER, J. A. (1968) The construction and description of algorithms. *Appl. Statist.* **17**, 175–179.

This paper introduces an algorithm section as a new feature of the journal. Some general recommendations concerning algorithm layout and design are made and the acceptable languages and standard (and optional) information to be given with every algorithm are described. The recommendations are given to encourage a uniform style of presentation, which will improve the effectiveness and readability of the algorithm section.

## Computer Department

### RESEARCH PAPERS

13.1 YATES, F. (1968) Theory and practice in statistics. Presidential Address to the Royal Statistical Society. *Jl R. statist. Soc. A.* **131**. (In the press.)

The relation between theory and practice in statistics is discussed. Much of the



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theory published recently in statistical journals seems largely irrelevant to practical problems confronting statisticians. Preoccupation with such theory has produced a wide gap between theoretical and practical statistics and has distorted teaching so that many statisticians start their careers without any clear idea of how to apply important and quite elementary methods. Some examples of misleading statistical work are given. The danger of misapplication of statistics is greatly increased now that electronic computers are becoming widely available.

13.2 YATES, F. (1969) The evolution of a survey analysis program. *Proceedings of Symposium on the Foundations of Survey Sampling, University of North Carolina, Chapel Hill.* (In the press.)

The paper describes the development of the survey analysis programs written for the Rothamsted computers, in particular the new General Survey Program just completed.

## Field Experiments Section

### RESEARCH PAPERS

14.1 GARNER, H. V. (1968) Field experiments on carrots at Rothamsted, Woburn and Tunstall (Suffolk). *Expl Hort.* No. 18, 69–76.

The results of carrot experiments done on the heavy loam at Rothamsted and on sandy soils at Woburn and Tunstall since 1942 are summarised. On acid sand carrots failed at pH 4·6, grew well at pH 5·0–5·3 but better still at pH 6·3. Potassium was the most important nutrient but nitrogen also increased yield. Farmyard manure at 8 tons/acre was very effective and dressings of 16 tons had large residual effects after 2 years at Tunstall and at Woburn increased yield by 13% even after 5 years. Farmyard manure greatly lessened the need for potassium and nitrogen. Grass-clover leys 3 years old ploughed in 5 years before carrots were sown increased the yield by 2·5 tons/acre, but lucerne leys similarly treated had little effect. Soil conditioners gave negligible increases at Rothamsted or Woburn.

14.2 MCEWEN, J. (1968) Crop rotations for experimental stations. *Expl Husb.* No. 16, 63–69.

Soil-borne pathogens and perennial weeds can cause difficulties in interpreting results of field experiments. At present the most effective control is by crop rotation. A scheme of land allocation incorporating a crop rotation is outlined. The rotations now practised at Rothamsted and Woburn are given as examples of modifications that can be made to the basic scheme to meet the needs of individual experimental stations.

## Broom's Barn Experimental Station

### GENERAL PAPERS

16.1 DUNNING, R. A. (1968) Docking disorder: nematicides bring hope for light sand crops. *Fmg Wld* (Sugar beet supplement), March.

16.2 HEATHCOTE, G. D. (1968) Menazon seed-treatment for aphids and virus control. *Br. Sug. Beet Rev.* **36**, 113–115.

16.3 HEATHCOTE, G. D. (1968) Aphids and the sugar beet crop. *Br. Sug. Beet Rev.* **36**, 171–173.



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16.4 SCOTT, R. K. (1968) Sugar-beet seed growing in Europe and North America. *I.I.R.B.* (*J. int. Inst. Sugar Beet Res.*) **3**, 54–84.

RESEARCH PAPERS

16.5 BYFORD, W. J. (1968) Laboratory experiments on sugar-beet downy mildew (*Peronospora farinosa*). *Ann. appl. Biol.* **61**, 47–55.

The optimum temperature for *Peronospora farinosa betae* to produce spores was 8–10° C at relative humidity 90% or more, but many spores were produced between 5 and 20° C and between 80 and 90% R.H. Most spores were formed in darkness after leaves were exposed to light for 6–8 hours. Spores survived exposure to 60% R.H. for up to 5 days, but were soon killed by temperatures above 20° C. The germination capacity of spores collected from the field was often very small, but this could not be related to the weather. Most seedlings were infected when inoculated at the growing point and incubated in a saturated atmosphere between 3 and 15° C for at least 8 hours.

16.6 BYFORD, W. J. & (WARD, L. K.) (1968) Effect of the situation of the aphid host at death on the type of spore produced by *Entomphthora* spp. *Trans. Br. mycol. Soc.* **51**, 598–600.

When *Phorodon humuli* and *Brachycaudus helichrysi* on plum were attacked by either *E. planchoniana* or *E. aphidis*, individuals that died on the leaves carried only conidia of the fungi, while those that wandered off the leaves and died in crevices of the bark contained only resting spores.

16.7 DRAYCOTT, A. P. & DURRANT, M. J. (1969) The effects of magnesium fertilisers on yield and chemical composition of sugar beet. *J. agric. Sci., Camb.* (In the press.)

Nineteen experiments were made between 1964 and 1967 on fields where previous sugar-beet crops showed symptoms of magnesium deficiency. None, 2·5 or 5 cwt/acre kieserite or 20 cwt/acre dolomitic limestone were tested in a factorial design with none or 3 cwt/acre agricultural salt, and 0·8 or 1·2 cwt/acre nitrogen as 'Nitro-Chalk'. Additional plots tested kainit (7 cwt/acre) and a large dressing of potash (2 cwt/acre) as muriate of potash.

Kieserite and dolomitic limestone increased sugar yield; the most effective dressing, 5 cwt/acre kieserite, increased sugar by 3·1 cwt/acre. Agricultural salt and the larger dressing of nitrogen were profitable, and neither interacted with magnesium on average; the large dressing of potash also increased yield. The magnesium in the kainit increased yield slightly, but the dressing tested supplied too little to satisfy the crop's requirement of magnesium.

Each year in late summer the percentage of plants showing magnesium deficiency symptoms was recorded, and a sample of twenty-four plants harvested from each of the magnesium treatments and analysed. All the magnesium fertilisers increased the concentration of magnesium in leaves, petioles and roots, and also decreased the number of plants showing deficiency symptoms.

The magnesium concentrations in plants grown without magnesium differed widely and were related both to the yield response to magnesium fertiliser and to the percentage of plants with deficiency symptoms. Both relationships showed a similar 'transition zone' from deficiency to adequate supply; for leaves this was 0·2–0·4% Mg, for petioles 0·1–0·2% Mg and for roots 0·075–0·125% Mg.

16.8 HEATHCOTE, G. D. (1968) The use of menazon seed dressing to decrease spread of virus yellows in sugar-beet root crops. *Ann. appl. Biol.* **62**, 113–118.

Menazon applied to sugar-beet seed decreased the proportion of seedlings



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infested with aphids during May and early June, and the number of aphids per plant during June and early July to one-third of that in control plots. It also checked the spread of virus yellows. Menazon seed dressing increased sugar yield by about 8 cwt/acre on eight field trials where untreated plots had more than 10% of the plants infected with yellows. Spraying with demeton-methyl when a 'spray warning' was issued in the area gave a similar increase, and had no further effect on plots sown with menazon-treated seed. Menazon-dressed sugar-beet is recommended where yellows is usually prevalent, or where there is reason to expect a large aphid infestation.

16.9 HEATHCOTE, G. D. (1968) Protection of sugar-beet stecklings against aphids and viruses by cover crops and aluminium foil. *Pl. Path.* **17**, 158–161.

Stecklings were grown without cover, between rows of mustard or barley, or with strips of aluminium foil between the rows. Stecklings in open beds were larger than those beneath cover crops. In 1966, stecklings in plots with mustard cover were most heavily infested with *Myzus persicae*, but in 1967 most were on plants in open beds. *Aphis fabae* were always most abundant in the open beds. Few plants beneath cover crops contracted virus yellows. The metal strip also decreased yellows incidence, but much less so than the cover crops, and less than they affected aphid infestation.

16.10 HEATHCOTE, G. D., PALMER, J. M. P. & TAYLOR, L. R. (1969) Sampling for aphids by traps and by crop inspection. *Ann. appl. Biol.* **63**, 155–166.

The catches of thirty aphid genera and species during three years in a suction trap at 40 ft and on a yellow cylindrical sticky trap at 5 ft at Rothamsted and Broom's Barn are tabulated. Suction-trap catches were the more consistent but both were more effective at recording the first seasonal immigration of *Myzus persicae* and *Aphis fabae* than the British Sugar Corporation crop-inspection scheme.

The catches show the differential attraction to yellow by different species, the effects of local vegetation and the seasonal distribution of aphids that are crop pests or potential vectors of viruses.

16.11 HULL, R. (1968) The effect of infection with beet yellows virus on the growth of sugar beet. *J. Am. Soc. Sug. Beet Technol.* **15**, 192–199.

The effect of infection with beet yellows virus (BYV) on sugar beet grown in culture solution in the glasshouse at Berkeley, California, was relatively greater on the tap root d.m. yield (45% decrease) than on the leaves (18%), crowns and petioles (38%) or the whole plant (32%). Comparable decreases for healthy plants defoliated to give the same leaf area duration as the BYV plants were 12% for the whole plant d.m. and 15% for the tap root. Of the total decrease in yield of d.m. by BYV, 72% was attributed to smaller leaves and 28% to the effect of the virus on the net assimilation rate; in contrast 33% of the decrease in tap root d.m. yield is attributable to smaller leaves and 67% to physiological effects. Water usage more nearly paralleled leaf area than size of the fibrous root system, which was significantly smaller for plants with BYV.

16.12 HULL, R. & SCOTT, R. K. (1969) A comparison of methods of growing sugar beet seed. *J. agric. Sci., Camb.* **72**, 109–117.

Two experiments with sugar-beet seed crops at Dunholme Field Station, Lincolnshire, 1955–57, one at Broom's Barn, Suffolk, 1963–64, and two in Bedfordshire, 1965–67, compared transplanting with various direct-drilling techniques. The early experiments were made with multigerm varieties and the 1965–67 experiments with genetic monogerm varieties. At Dunholme direct drilling under a



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barley cover crop controlled virus yellows and yielded more multigerm seed suitable for processing than did transplanting. In later experiments, transplanting gave variable yields; pests damaged plots transplanted in autumn and those transplanted in spring were susceptible to drought. Many transplants lodged and ripened late, and direct drillings produced seed that germinated better.

Direct drilling during July with no cover crop consistently yielded better than undersowing or open drilling in August. To establish a regular, dense stand of plants, which is essential for large yields of seed of good germination, was more difficult with than without cover crops. The time the cover crop was removed did not consistently affect yield. Crops sown in summer without cover yielded most seed but were most susceptible to disease and are unsuitable for areas with a disease risk.

16.13 LAST, P. J. & TINKER, P. B. H. (1968) Nitrate nitrogen in leaves and petioles of sugar beet in relation to yield of sugar and juice purity. *J. agric. Sci., Camb.* **71**, 383–392.

The use of the correct N dressing for beet is important, as any excess decreases juice purity and profit, and may decrease sugar yield, but no analytical method will at present predict the best dressing in any particular field. The concentration of nitrate in leaves and petioles of beet was determined to test if it would determine the need for top-dressings of N. Beet on 17 field trials in three years testing N were sampled. Nitrate in wet tissue extract was determined by reducing to ammonia with titanous sulphate and subsequent distillation.

The petiole nitrate concentration decreased sharply with time, from around 1000 ppm in wet tissue in early June to less than 100 ppm. in early September. The nitrate concentrations were closely related to nitrogen dressing, and the rapid decline in concentration was decreased by top-dressings. Comparison of samples taken in June showed that most of the variation between the experiments could be accounted for by the different ages of the plants. Sodium fertiliser had no effect on nitrate content. Petiole nitrate was inversely related to juice purity and sugar concentration, especially when the nitrate content exceeded 700 ppm. in June. On average, petiole nitrate concentrations about 800 ppm. in June were associated with the largest sugar yields, but the content could not be used to predict nitrogen top-dressing requirement accurately at individual sites. Measuring $NO_3$-N cannot at present be recommended as a method for deciding how much nitrogen fertiliser to use, but it has value for detecting severe deficiencies and in research.

## Soil Survey of England and Wales

### BOOKS

17.1 CARROLL, D. M. & BASCOMB, C. L. (1967) Notes on the soils of Lesotho. *Tech. Bull. Land Resources Division, Directorate of Overseas Surveys*, No. 1. vi, 75 pp.

17.2 GREEN, R. D. (1968) *Soils of Romney Marsh.* Harpenden: Rothamsted Experimental Station, ix, 158 pp.

17.3 JARVIS, R. A. (1968) *Soils of the Reading District.* Harpenden: Rothamsted Experimental Station, viii, 150 pp.

### GENERAL PAPERS

17.4 CRAMPTON, C. B. (1967) The evolution of soils on the hills of South Wales, and factors affecting the distribution, and their past, present and potential use. *Rep. Welsh Soils Discussion Group* No. 8, 52–69.



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17.5 CRAMPTON, C. B. (1968) Pre-historic flora in the South Wales Upland, Britain. In: *Advancing frontiers of plant sciences.* New Delhi.

RESEARCH PAPERS

17.6 AVERY, B. W. (1968) General soil classification: hierarchical and co-ordinate systems. *Trans. 9th int. Congr. Soil Sci., Adelaide* **4**, 169–175.

The fundamental limitations of soil are considered, and it is concluded that a co-ordinate classification based on well-defined attributes of the soil or of the environment has advantages as a general reference system, as a means of epitomising soil relationships effectively, and as a basis for soil surveys.

17.7 BASCOMB, C. L. (1968) A new apparatus for recording particle size distribution. *J. sedim. Petrol.* **38**, 878–884.

A manometer and sensitive capacitance transducer follow the drop in hydrostatic pressure at a point near the bottom of a column of soil suspension, during sedimentation. Current from the transducer is fed to a recorder, which traces an accumulation curve. The first derivative (slope of the curve) gives a summation curve of the particle size distribution.

Results on four soils with different particle size distributions agree with those obtained by a standard pipette-sampling/sieving procedure over the range 20–200 μ effective settling diameter.

17.8 BASCOMB, C. L. (1968) Distribution of pyrophosphate-extractable iron and organic carbon in soils of various groups. *J. Soil Sci.* **19**, 251–268.

Potassium pyrophosphate (0·1M) removes very little Fe from crystalline Fe oxides at pH 10, but peptises finely divided hydrous amorphous oxides and organic matter in soils.

Fe and C contents of extracts from each horizon of 26 British soil profiles show distinctive patterns, independent of the residual dithionite-soluble Fe. Thus extracts of humus Fe podzols have maximum Fe and C in the B horizon, whereas a peaty gley podzol has maximum Fe in the B horizon but maximum C in the surface. These groups are differentiated from non-podzols which have maximum pyrophosphate extractable Fe and C in the surface horizon, decreasing with depth. Intermediate patterns help to quantify differences in soils of classes having properties of more than one soil group.

17.9 CRAMPTON, C. B. & (TAYLOR, J. A.) (1967) Solifluction terraces in South Wales. *Biul. peryglac.* No. 16, 15–36.

A hypothesis is proposed to explain the formation of certain terrace deposits in the upland valleys of South and Central Wales. It is suggested they were originally formed during late Würm or post-Würm periglacial phases when the substratum was permanently frozen, but thin layers of surface debris moved downslope with periodic freezing and thawing. Solifluction began on the warmer south- and west-facing slopes before the colder north- and east-facing slopes. The resulting material accumulated on the valley floor and also tended to move gravitationally down-valley, later accentuated by melt water and then by stream erosion which deformed the terraces and locally led to their disappearance. The terraces now seen are merely remnants of the last periglacial phase.

17.10 MATTHEWS, B. (1967) Automatic measurements of frost-heave; results from Malham and Rodley (Yorkshire). *Geoderma* **1**, 107–115.

A pen-arm recorder, giving a continuous trace of both short-term (diurnal) and long-term frost-heave movements in soil is described.



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Measurements at Malham and Rodley illustrate the effects of frost in areas of loamy till in the Pennine foothills and areas of silty drift in the Pennine uplands.

17.11 PETTERSSON, M. (1968) Indications of provenance of some Anglesey drift soils. *J. Soil Sci.* **19**, 168–173.

A study of the heavy mineralogy of the fine-sand and stone fractions and the particle-size distribution and CEC of samples from 30 Anglesey drift-derived soils suggests that the soil stones are an unreliable guide to the parent material of the soil as a whole. The chief lines of evidence are: the small degree of dependency of soil- and stone-heavy mineralogy, the slight translocation of most stones, and the great similarity of soils containing very different stone assemblages.

MAP

17.12 CROMPTON, A., CRAMPTON, C. B., CURTIS, L. F., (KAY, F. F.) & MITCHELL, W. A. (1968) Soil Map, 3rd Edition Sheet 74 (Leeds) 1:63360, Southampton: Ordnance Survey.



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