ROTHAMSTED RESEARCH

Rothamsted Report for 1963

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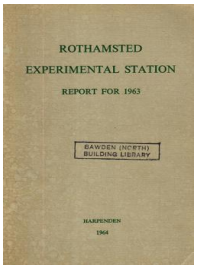

Abstract of Papers

Rothamsted Research

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ABSTRACTS OF PAPERS

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Physics Department

General Papers

1.1 Penman, H. L. (1963) Fifty years of physics at Rothamsted. *Bull. Inst. Phys.* **14**, 293–299.

1.2 Penman, H. L. (1963) Mirror for meteorologists. *Quart. J. R. met. Soc.* **89**, 453–460.
Presidential address to the Royal Meteorological Society.

1.3 Penman, H. L. (1964) Soil moisture deficit. *Proceedings of the 2nd World Congress on Agronomic Research*, held in Rome, 1963. III, 3.

1.4 Penman, H. L. with (Angus, D. E.) (Australia) & (van Bavel, C. H. M.) (Arizona, U.S.A.) (1964) Micro-climatic factors in irrigation. In: *Irrigation of Agricultural Lands*. (American Society of Agronomy). Chapter 27. (In the press.)

Research Papers

1.5 Long, I. F. (1963) Fossil hail prints. *Weather* **18**, 115.

1.6 Long, I. F. & Penman, H. L. (1963) The micro-meteorology of the potato crop. In: *The growth of the potato*. London: Butterworth, pp. 183–190.

Diagrams of the profiles of wind speed, air temperature and humidity, and energy balances, are compared for two periods; first, early in July 1955 near the beginning of a drought, and second, in mid-August when the drought was interrupted by a wet day. There is evidence (not conclusive) that the crop may need two days before it responds to rain, perhaps because new roots must grow towards the newly arrived water in the surface soil.

1.7 Monteith, J. L. (1963) Calculating evaporation from diffusive resistances. In: *Investigation of energy and mass transfers near the ground*. . . . Final Report, University of California, Davis, California, Chapter 10, pp. 177–189.

The conventional flux equations for aerodynamic transport of heat and water vapour are modified to take account of the origin of the water vapour inside plant leaves by introducing a stomatal resistance (r_s) with the dimensions sec/cm. From detailed measurements of evaporation and energy exchanges on 4 days in 1962 values of stomatal resistance for grass ranged from 0·4 near midday to values over 1·0 early and late in the day. The mean monthly evaporation rates, measured in 1960 on a 20-ft-diameter lysimeter at Davis, were then calculated from the Davis weather records with two values of stomatal resistance of 0·4 and 0·8 sec/cm. The agreement between calculation and measurement is good for both values, and for January to May, plus December, is very good with $r_s = 0{\cdot}4$, and for June to November is very good with $r_s = 0{\cdot}8$ sec/cm.

The physiological behaviour of plant surfaces may control evaporation, even when soil moisture is maintained by frequent rain or irrigation.

1.8 Penman, H. L. (1963) Weather and water in the growth of potatoes. In: *The growth of the potato*. London: Butterworth, pp. 191–198.

For maximum growth of potatoes the soil moisture deficit should not exceed about 1 in. rainfall equivalent. Assuming that there is no growth in periods

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when the deficit is greater than 1 in., and still increasing, an adjusted potential transpiration, $E_T(A)$, integrated over growth periods, is a useful growth index. Previously a linear relation had been obtained for Woburn yields against $E_T(A)$: almost as good a relation is now obtained for yields from the Rothamsted six-course rotation 1942–60. Implicit in the interpretation is the assumption that the rate of growth of the tubers in any year is proportional to the rate of increase of $E_T(A)$. This was confirmed from seven sets of measurements of bulking rate taken 1941–45.

It seems that the primary effect of weather on potatoes, acting through its modification of the root environment, can be expressed quantitatively, so that when a crop fails it should be possible to assess how far "bad weather" can be blamed, and, thereafter, if necessary, to search for non-meteorological causes of the failure.

1.9 PENMAN, H. L. (1963) Irrigation in Britain. *J. R. Soc. Arts*, **111**, 272–289.

By 1960 the increasing use of irrigation as a farming technique provoked the Central Advisory Water Committee into asking for an estimate of probable requirements in 20 years' time. This paper reviews the scientific reasoning and field experiments that contributed to the estimate provided by a Working Party for the Committee. There are three aspects of the problem. (*a*) Why do plants need water? (*b*) How is the need determined by weather? (*c*) How is growth affected when part or all of an estimated shortage of rain is made good by irrigation? The answer to (*b*), set out in a Technical Bulletin in 1954, suggested that near Woburn summer rainfall would be deficient in 7/10 years for a crop such as grass. After 12 years' collection of results for (*c*), on a range of farm crops, out of 48 pairs of comparisons of irrigated *v.* non-irrigated yields, 33 pairs gave more than 10% increase and 19 pairs more than 25% increase. Within these general averages some crops respond almost every year (grass, potatoes), others respond only in very dry summers (sugar beet), and there is a middle range near the average (spring cereals, beans). Combining Woburn results with those from elsewhere, including vegetables and fruit, and weighting the value of the responses against the cost of the water, the order of priority is: Vegetables, Fruit, Potatoes, Grass, if intensively used, Sugar Beet, Field Beans, Cereals. In considering the possible development against the existing pattern of British agriculture the Working Party estimated that perhaps 10% of England and Wales might be irrigated. On the way to this total a worthwhile stage would be about half a million acres irrigated by 1980, which is what will be reached if the current rate of expansion is maintained.

1.10 ROSE, D. A. (1963) Water movement in porous materials: Part 1—Isothermal vapour transfer. *Brit. J. appl. Phys.* **14**, 256–262.

The isothermal movement of water vapour through six different porous materials (both consolidated and granular) was studied using cylindrical samples (5 cm diameter and 1·2 cm deep) in a simple diffusion cell. Two flow regimes occur. Initially, as moisture content θ/θ_T increases, the apparent conductivity (k' cm sec^{-1}) increases rapidly, confirming predictions of Philip and de Vries (1957) that a discontinuous liquid phase can enhance water movement by transmitting a vapour flux and thus acting as a short-circuit path for vapour. When liquid continuity is established, however, further increase in θ/θ_T causes k' to rise slowly to a limiting value dependent on the thermal conductivity of the material, suggesting that liquid flow is inhibited by a back hydromotive force set up by unavoidable temperature gradients produced by

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condensation and evaporation. Apparent diffusivities (D' cm^2 sec^{-1}) increase rapidly as θ/θ_T increases, as predicted by Philip (1955) for vapour movement. The cell gives quick and reproducible estimates of water potential in the range pF 2·5–5·6.

1.11 Rose, D. A. (1963) Water movement in porous materials: Part 2—The separation of the components of water movement. *Brit. J. appl. Phys.* **14**, 491–496.

Vapour conductivities k_V estimated from hydrogen diffusion in porous solids of decreasing moisture content θ rise slowly from zero at saturation θ_T to a maximum near dryness, and then fall rapidly again to zero at complete dryness. Liquid conductivities k_1, computed from pore size distributions, and estimated from previous water-transport experiments, decrease continuously from saturation to complete dryness. For each of six different porous materials the proportion of water movement as vapour falls rapidly as θ increases, becoming negligible in the moisture range important for plant growth.

Six stages in the wetting of a porous system can be identified. Once adsorption is complete, unimpeded vapour transfer occurs, together with liquid movement. The latter takes the form, as θ increases, of distillation (a discontinuous liquid phase acting as a short-circuit for vapour), followed by surface creep (flow in continuous liquid films with k_1 increasing as $(\theta/\theta_T)^n$ with $n \simeq 3$) and unsaturated hydraulic flow. Finally, at saturation, $k_V = 0$, and saturated hydraulic flow obtains.

1.12 Szeicz, G., Monteith, J. L. & Dos Santos, J. M. (1964) Tube solarimeter measuring radiation among plants. *J. Appl. Ecol.* **1**. (In the press.)

Copper-plated constantan wire measures the temperature difference between black and white painted segments of a thermopile surface, 1 in. wide and 33 in. long, mounted inside a 1-in.-diameter glass tube. Sensitivity is about 40 mV/cal cm^{-2} min^{-1}, decreasing when the tube is about parallel to the solar beam, so in use the units are mounted east–west. Infra-red radiation is recorded by tubes containing a Wratten 88A gelatine filter (transmitting beyond 0·75 μ) and visible radiation (0·4–0·75 μ) is calculated from the difference of infra-red and total radiation. Radiation profiles in barley and kale show a strong preferential absorption of visible light.

1.13 Waggoner, P. E., Monteith, J. L. & Szeicz, G. (1964) Decreasing transpiration of field plants by chemical closure of stomata. *Nature, Lond.* **201**, 97–98.

In July 1963, barley was sprayed with $10^{-3}M$ half methyl ester of nonenyl succinic acid (NSA) and stomatal closure was demonstrated by porometer measurements. On the day after spraying, transpiration from sprayed plots was about 20% less on average than from unsprayed controls, but effects of the spray were undetectable after 3 or 4 days.

Chemistry Department

Thesis

2.1 Cunningham, R. K. (1963) Cation–anion relationships in plants. Ph.D. Thesis, University of London.

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General Papers

2.2 Cooke, G. W. (1963) Soils and fertilisers. *J. R. agric. Soc.* **124**. 137–160.

2.3 Cooke, G. W. (1962) The effect of fertilisers on the yield and composition of cereals with special reference to barley. *Irish Maltsters Conference Selected Papers* 1952–1961. Dublin: Arthur Guinness Son & Co. Ltd., pp. 55–73.

2.4 Cooke, G. W. (1963) British research on potassium in soils and fertilisers, 1952–1962. *Potash Review*, Subject 16, 26th Suite, 8 pp.

2.5 Cooke, G. W. (1963) Fertiliser availability. In: *Crop production in a weed-free environment. Symposium of the British Weed Control Council*. No. 2. Oxford: Blackwell Scientific Publications, pp. 50–54.

2.6 Cooke, G. W. (1963) Inorganic fertilisers *and* The use of fertilisers. In: *Farming*, ed. A. N. Duckham, London: Caxton Publishing Co., Chapter 5, pp. 99–112, Chapter 6, pp. 113–128.

2.7 Cooke, G. W. (1963) Placement and timing of fertiliser application. *Pwr Fmg Aust. N.Z.* **72**, No. 5, 7–9, 94.

2.8 Cunningham, R. K. (1963) What shade and fertilisers are needed for good cocoa production? *Cocoa Gr. Bull.* No. 1, 11–16.

Research Papers

2.9 Cunningham, R. K. (1963) The effect of clearing a tropical forest soil. *J. Soil Sci.* **14**, 334–345.

Organic matter in tropical soils under forest is delicately balanced, the continuous addition of fresh material being offset by decomposition. The forest was removed from a soil in Ghana and three degrees of exposure were tested. Chemical and physical properties were measured from 1957 to 1960. Much organic C, total N and organic P was lost from the soil of fully exposed plots, because soil temperatures increased and fresh organic matter was no longer provided by the forest. Rate of decomposition lessened with time. Decomposition under shade, though still rapid, was significantly slower than in exposed soil. After three years' exposure the soil produced less mineral N and had smaller cation exchange capacity, exchangeable K, and lower pH than the shaded soil. Exposure also compacted the soil, impeded drainage through the 2–6-in. layer and made the soil erode more easily.

2.10 Cunningham, R. K. & Nielsen, K. F. (1963) Evidence against relationships between root-cation exchange capacity and cation uptake by plants. *Nature, Lond.* **200**, 1344–1345.

Although the root-cation exchange capacity of Italian ryegrass (*Lolium multiflorum*) was not affected by soil temperature, level or form of N, these factors altered the sum of the cations and the ratio of divalent : monovalent cations in the grass.

2.11 Gasser, J. K. R. (1962) Effects of long-continued treatment on the mineral nitrogen content and mineralisable nitrogen of soil from selected plots of the Broadbalk Experiment on continuous wheat, Rothamsted. *Plant & Soil* **17**, 209–220.

The changes in the ammonium-N and nitrate-N contents of bare fallow and soil under the first and third crops of winter wheat after fallow were followed

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on plots of Broadbalk Field, Rothamsted, which have received for each crop 14 tons farmyard manure (FYM) per acre, "complete minerals" (P, K, Na, Mg), or "complete minerals" + nitrogen fertilisers.

More mineral N was produced during fallow on the plot receiving FYM than on the other plots. Soil under wheat also contained more mineral N on the FYM plots than elsewhere. Nitrogen fertilisers applied in the spring temporarily increased the mineral-N content of the soil, but were rapidly removed by the crop. Ammonium sulphate applied in the autumn was lost from the surface soil by the following March by nitrification and leaching.

Twice as much mineral-N was produced by incubation of soil from the FYM plot as by incubation of soils from other plots. Nitrate formed during fallow was leached into the subsoil during the autumn and winter, and recovered by the wheat during the following spring and summer. Its existence is not detected by sampling the surface soil or by an incubation test. This source of nitrogen complicates the use of laboratory measurements to assess the fertiliser nitrogen required by winter wheat.

2.12 GASSER, J. K. R. (1961) Investigations on rice-growing in British Guiana. I. Characteristics of some rice soils of the Coastland. *J. Soil Sci.* **12**, 234–241.

An attempt was made to account for the different soil types derived from alluvial material of similar age and origin. The sequence noted was undifferentiated alluvium (frontland clay soil), humose clay (pegassy-clay soil), thin organic soils (pegasse). The subsoil ranged from one similar to frontland clay to a bleached yellowish-white structureless clay, differences attributed to differing durations and intensities of flooding. With permanent flooding, plant residues accumulate on the surface and the soil is more rapidly leached. Less organic matter accumulates and less leaching occurs with seasonal flooding. Reefs of dry sand and other soils develop under special conditions and, as they do not belong to the general sequence, are described separately.

2.13 GASSER, J. K. R. (1962) Investigations on rice-growing in British Guiana. II. Field experiments to test effects of fertilisers, lime and cultivations on yield, composition and nutrient uptake. *J. Soil Sci.* **13**, 321–332.

Factorial experiments were done to test the effects of N, P and K fertilisers and lime on grain and straw yields. In addition, deep ploughing was compared with shallow, static with flowing irrigation, and in two Latin-square experiments alternative P fertilisers were tested.

Nitrogen fertilisers increased yields most on the most fertile soil type. Phosphorus fertilisers did not increase yields on the most fertile soil type, gave a moderate increase on the less fertile soils and prevented crop failure on soil containing much exchangeable Al. On the last soil type water-soluble phosphates were more effective than basic slag. Potassium fertilisers improved early growth at one site, but did not increase straw and grain yields. Lime did not increase yields, even on the very acid soil containing much exchangeable Al.

The weight of 100 whole grains was determined for rice from experiments sown with "pure-line" seed. Increased weight was normally found only when the field treatment increased yield.

The N, P, K and Ca contents of, and uptake by, straw and grain were determined for three sites differing in responses to applied N and P. Fertiliser N and K had little effect on the composition of straw or grain. Fertiliser P increased the P and decreased the N contents of straw and grain on P-deficient soils. Fertiliser P also decreased K content of the straw, increased that of the

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grain at one site and also increased the Ca content of straw and grain. Lime increased the Ca content of the straw and of the grain at one site. Uptake of nutrients was affected more by yield than by composition.

2.14 GASSER, J. K. R. (1963) A substitute reagent for titanous sulphate for reducing nitrate-N. *Analyst* **88**, 237–238.

As commercial titanous sulphate was unobtainable, a substitute reagent was prepared from titanous chloride.

2.15 GASSER, J. K. R. & WILLIAMS, R. J. B. (1963) Soil nitrogen. VII. Correlations between measurements of nitrogen status of soils and nitrogen % and nitrogen content of crops. *J. Sci. Fd Agric.* **14**, 269–277.

Laboratory measurements of "available" soil-N were used to try to assess its effect on dry matter, N content and N% of ryegrass grown in pots, of barley and wheat seedlings grown in boxes and of barley grain from field crops grown on soils without fertiliser-N. Mineral-N in the fresh soil (Mineral-N_{fresh}) and the increase when fresh or rewetted air-dry soils were incubated (Δ Mineral-N_{fresh} or Δ Mineral-$N_{air\text{-}dry}$) were all significantly correlated with yields and N contents of ryegrass, barley and wheat seedlings and barley grain. These soil-N measurements were also significantly correlated with N% in barley grain and sometimes N% in ryegrass and in barley and wheat seedlings. Δ Mineral-$N_{air\text{-}dry}$ was significantly correlated most often. Soil-N measurements were correlated better with N contents of crops than with yields of dry matter.

2.16 HEINTZE, S. G. (1963) Note on the availability of magnesium in basic slags. *J. Sci. Fd Agric.* **14**, 324–329.

Pot experiments, designed to measure effects produced solely by Mg, showed that two basic slags of similar Mg content and made by the same process differed in the extent to which the Mg was available to grass and in the yield of grass obtained; a slag containing much less Mg had negligible effect on yield on an acid soil and did not release Mg to either acid or basic soil. Additions of calcium carbonate or magnesium sulphate increased yields of grass from an acid, magnesium-deficient soil containing little exchangeable Mg, and each increased the uptake of Mg. The amount of magnesium released when soils were incubated with slags agrees with results from pot experiments.

2.17 MATTINGLY, G. E. G. (1963) The agricultural value of some water- and citrate-soluble phosphate fertilisers: an account of recent work at Rothamsted and elsewhere. *Proc. Fertil. Soc.* No. 75, 57–97.

None of the newer fertilisers has been significantly and consistently better than superphosphate, and many, in the forms in which they were manufactured and tested, have been worse. Finely powdered dicalcium phosphate dihydrate has generally been as good as superphosphate for potatoes and swedes on acid soils, but less effective than superphosphate for swedes on neutral soils, for kale on acid soils and for permanent grass on both neutral and acid soils. The value of nitrophosphate fertilisers depended on their method of manufacture and the crops for which they were used. Nitrophosphates made by the process in which calcium nitrate is removed before ammoniating, and containing 10–20% water-soluble P, were unsuitable for potatoes. These fertilisers, with over 50% of their granules greater than 3 mm diameter, were more effective for permanent grass and for swedes. Nitrophosphates made by adding ammonium sulphate before ammoniating had

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about 30% of their total phosphate in a water-soluble form. They were 60–80% as effective as superphosphate for potatoes, the smaller value corresponding to a product in which 40% of the total phosphorus was insoluble in alkaline ammonium citrate and present as a phosphate more basic than dicalcium phosphate. Nitrophosphates made from mixed nitric and sulphuric acids (principally 2–4-mm granules) gave percentage superphosphate equivalents of 62, 61 and 96% respectively for potatoes, grass and swedes.

Experiments with cereals and radish suggest that early growth is approximately proportional to the amount of water-soluble phosphate in the fertilisers. The water-insoluble phosphate in granular nitrophosphates (60–70% of the granules less than 3 mm diameter) seemed not to be used by barley up to ear-formation. Yields of ryegrass were almost independent of the amount of water-soluble phosphate, and granular nitrophosphates applied before sowing were as effective at the end of one growing season as superphosphate of the same granule size.

The residual values of different forms of phosphate fertilisers in rotation experiments lasting for 3 years differed less than in annual experiments. Potatoes, barley and swedes on an acid soil yielded the same with granular nitrophosphates (containing between 5 and 50% water-soluble phosphate), potassium metaphosphate and high-soluble basic slag as with granular superphosphate. Rock phosphate gave smaller yields of potatoes on acid soils than the other fertilisers but similar yields of barley and swedes. Basic slag and rock phosphate had less residual value than superphosphate for potatoes on neutral soils. Basic slag and powdered dicalcium phosphate dihydrate were approximately equivalent to superphosphate, over a period of three years, for barley and swedes on neutral soils, whereas rock phosphate was almost useless.

2.18 MATTINGLY, G. E. G. (1963) Residual value of superphosphate and rock phosphate on an acid soil. II. Soil analysis and greenhouse experiments. *J. agric. Sci.* **60**, 409–414.

Analyses and a greenhouse experiment on soils taken from a field experiment to estimate residual values of phosphates were used to show changes in the amount and distribution of residual phosphate in the soil. Total and $NaHCO_3$-soluble P were large in the top 0–3 in. of soil after applying superphosphate. Total P was large, but $NaHCO_3$-soluble P much less where rock phosphate had been applied in the field. Ploughing distributed total and $NaHCO_3$-soluble P more uniformly through the 0–6 in. layer of soil. Soil analysis and crop yields in the greenhouse showed that the residual value of equal amounts of P_2O_5 as rock phosphate and superphosphate, 3 years after application, were very similar. At the end of the field experiment the sand fraction of the soil (2,000–75 μ) contained about 80% of the phosphate that was applied as rock phosphate in this particle-size range.

2.19 MATTINGLY, G. E. G. & WIDDOWSON, F. V. (1963) Residual value of superphosphate and rock phosphate on an acid soil. I. Yields and phosphorus uptakes in the field. *J. agric. Sci.* **60**, 399–407.

A field experiment on an acid soil long in arable cropping at Rothamsted measured residual effects of superphosphate, applied at several rates, and Gafsa rock phosphate applied at a single rate. Residues were valued after 1 year with barley, and after 2 years with ryegrass.

"Percentage fresh superphosphate equivalents" of residues of superphosphate for barley varied with the growth of the crop and with the method used to calculate them. They were 21–24% 6 weeks after sowing, measured from yield, P uptake or isotope dilution. At harvest they were 26% from yield, 43%

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from P uptake and 49% by isotope dilution. "Percentage fresh superphosphate equivalents" 6 weeks after sowing increased with the rate of superphosphate, but at harvest were independent of rate. "Percentage superphosphate equivalents" of Gafsa rock phosphate were much smaller; they increased from 2–3% 6 weeks after sowing to 7–12% at harvest.

With ryegrass "percentage fresh superphosphate equivalents" of residues of superphosphate applied either 1 or 2 years previously also varied with growth. All methods of valuation showed that residues were about twice as effective after 1 year as after 2 years in the soil. "Percentage fresh superphosphate equivalents" derived from P uptake remained constant during growth and were 37–38% for superphosphate applied 1 year before and 18–20% for superphosphate applied 2 years before. Values derived from ryegrass yields decreased during growth from 76 to 45% (1-year residues) and from 38 to 21% (2-year residues).

After cropping with barley for 2 more years there was little difference between yields or P uptakes from equal amounts of superphosphate whether applied 3 or 4 years previously. Residues from rock phosphate were almost equivalent to those from superphosphate after 3–4 years.

Apparent recoveries of superphosphate, as percentages of the amount applied, decreased with rate. The apparent recovery of P by crops in 5 years was about 21% from superphosphate and about 10% from rock phosphate when both were applied at 3·0 cwt P_2O_5/acre.

2.20 MATTINGLY, G. E. G., (RUSSELL, R. D.) & JEPHCOTT, B. M. (1963) Experiments on cumulative dressings of fertilisers on calcareous soils in South-West England. II. Phosphorus uptake by ryegrass in the greenhouse. *J. Sci. Fd Agric.* **14**, 629–637.

P status of calcareous soils was evaluated in two greenhouse experiments using ryegrass as a test crop. Soils were arranged by yields into very responsive, moderately responsive and slightly responsive groups, and mean values for all methods of soil analysis increased in the same order. P uptake by ryegrass, 40 days after sowing, from soils given superphosphate for 5–7 years in the field correlated most closely ($r = 0{\cdot}990$–$0{\cdot}959$) with 0·5*M*-sodium bicarbonate-soluble P and least closely ($r = 0{\cdot}822$–$0{\cdot}697$) with 1% citric acid-soluble P. P uptake during the first weeks of growth depended partly on the monocalcium phosphate potential measured on soils before cropping, whereas total P uptake in 4 months was closely correlated ($r = 0{\cdot}979$) with the labile P the soils contained, but was almost independent of the initial phosphate potential. The soils from different experiments differed more in the total quantity of P in the labile pool than in their capacity, defined as the change in the chemical potential of monocalcium phosphate per unit change in total labile P. Ammonium sulphate applied at 3 cwt/acre for 5 years in the field to Lulsgate series soils significantly increased P soluble in 0·01*M*-calcium chloride and 0·5*M*-sodium bicarbonate, labile P, yield and P uptake in the greenhouse.

2.21 WIDDOWSON, F. V., PENNY, A. & COOKE, G. W. (1963) Results of an experiment at Rothamsted testing farmyard manure and N, P and K fertilisers on five arable crops. I. Yields. *J. agric. Sci.* **60**, 347–352.

A rotation experiment was begun at Rothamsted in 1956 on a field where grass had grown for many years. Responses to combinations of N, P and K fertilisers and farmyard manure (FYM) were measured in wheat, kale, barley, grass–clover ley and potatoes grown in rotation. Two rates of N were tested. A strip of permanent grass had the same treatments as the arable crops.

Winter wheat yielded most dry matter, but wheat yields were increased

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least, proportionally, by added nutrients. Potatoes gave the smallest yield without manure and responded most to nutrients, yields being increased almost sixfold by NPK fertiliser plus FYM. Kale, barley and grass–clover ley were intermediate in their unmanured yields and in their responses. All crops except the grass–clover ley responded to N; kale responded most and wheat least. Potatoes, kale and barley responded about equally to P and needed this nutrient more than either wheat or the ley. Potatoes responded most to K, yields of wheat and clover ley were also small without K, but barley and kale needed K less. Interactions between nutrients were large with most crops, particularly with N on kale and K on potatoes, wheat and clover. FYM greatly increased yields of all crops, but responses were less when fertilisers were also given. Potatoes responded most to FYM whether or not fertilisers were also used. FYM also caused large increases in yields of grass–clover ley, kale and permanent grass.

2.22 WIDDOWSON, F. V., PENNY, A. & WILLIAMS, R. J. B. (1963) An experiment comparing responses to nitrogen fertiliser of four grass species. *Exp. Husb.* No. 9, 28–36.

From 1958 to 1960 the yields of cocksfoot (S.37), meadow fescue (S.215), perennial ryegrass (S.24) and timothy (Scotia) were compared without N and with 0·3 or 0·6 cwt N/acre per cut (as "Nitro-Chalk"). When N was not given, cocksfoot yielded less than the others, all of which yielded equally. With 0·3 or 0·6 cwt N/acre per cut, cocksfoot yielded most and perennial ryegrass least dry matter. The yield advantage of cocksfoot was greatest with 0·6 cwt N/acre. Timothy yielded more than meadow fescue. At each N level cocksfoot recovered most and perennial ryegrass least of the applied N. Grass grown with 0·6 cwt N/acre per cut took up much more K in 3 years (maximum 712 lb/acre) than was applied as fertiliser (279 lb K/acre). Consequently, the amount of HCl-soluble K in the surface soil decreased. Total P dressings (73 lb P/acre) almost met maximum uptake (78 lb/acre).

2.23 WIDDOWSON, F. V., PENNY, A. & WILLIAMS, R. J. B. (1963) Experiments comparing yield, and residual effects on winter wheat, of 1-year clover, ryegrass and clover–ryegrass leys. *J. agric. Sci.* **61**, 397–408.

Leys were undersown in barley in 1958 and were harvested in 1959 and their residual effect measured by winter wheat grown in 1959–60. When N was not given to wheat most grain and straw was obtained after clover ley and least after ryegrass given no N. The residual N from clover was equivalent to a fresh top-dressing of 0·14 cwt N. When the wheat received N fertiliser N given to ryegrass in 1959 decreased the 1960 wheat yield, probably because the ryegrass removed too much K.

Further leys were established under barley in 1960 and were cut in 1961; their residual effects were measured by winter wheat in 1961–62. Wheat harvested in June, at ear emergence, yielded most after clover ley and least after ryegrass that had not received N. When N was not given to wheat it yielded 20 cwt/acre more dry matter after clover than after ryegrass grown without N. Applying N to ryegrass decreased percentage K in wheat and also K uptake; 2·0 cwt K/acre was needed to maintain percentage K in wheat following ryegrass given 2·0 cwt N/acre. Maximum K uptake by wheat after clover was 1·33 cwt K/acre.

When N was not given to wheat 1962 grain yields were greatest after clover and least after ryegrass that had received no N; the grain yield after clover was 16·1 cwt/acre greater than the yield after ryegrass. N residues from the pure clover ley, ryegrass–clover ley, grown without N or with 1·0 cwt N/acre,

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were equivalent to 0·57, 0·25 and 0·16 cwt/acre N as fresh top-dressing, respectively. When 0·5 or 1·0 cwt N/acre, but no K, was given to wheat, yields were negatively correlated with the N given to ryegrass; 2·0 cwt K/acre was needed to maintain yield after ryegrass given 2·0 cwt N/acre. N uptakes in June and at harvest were correlated, but K uptakes were not. The greatest grain K uptake at harvest (0·22 cwt K/acre) was only one-sixth of the maximum K uptake in June; grain K uptake was little affected by ley, but was decreased by K fertiliser.

2.24 WILLIAMS, R. J. B. (1963) A new method for measuring soil stability. *Chem. & Ind.* 1032–1033.

A very sensitive method of measuring changes in pore space that result when soil slakes in water is described. It detects the beginning of structural degradation after soil under grass is ploughed for arable crops as well as the effects of practices that improve structure.

2.25 WILLIAMS, R. J. B., COOKE, G. W. & WIDDOWSON, F. V. (1963) Results of an experiment at Rothamsted testing farmyard manure and N, P and K fertilisers on five arable crops. II. Nutrients removed by crops. *J. agric. Sci.* **60**, 353–357.

All the crops grown responded well to P and K fertilisers, and all except clover responded to N. Uptakes from soil alone are therefore the maximum amounts of each nutrient that each crop could remove when supplied with other fertiliser nutrients. Permanent grass (free from legumes) obtained about 114 lb N/acre each year from soil and other natural sources, winter wheat obtained 100 lb N, kale and potatoes about 80 lb N and spring barley only 57 lb. A 1-year ley of clover and grass fixed at least 1 cwt N/acre/year. Permanent grass removed most P from soil (17 lb/acre a year), potatoes removed least (6 lb of P) and other crops intermediate amounts. Most K was taken from soil by kale (70 lb K/acre/year) and least (20 lb) by potatoes. The amounts of nutrients recovered from soil by any one crop differed more in different years with K than with N or P. Most fertiliser N was recovered by kale and least by potatoes; with these crops two-thirds and one-third respectively of the light dressing was recovered, percentage recovery decreased with increase of N. Kale and the 1-year ley recovered nearly one-quarter of the P applied, permanent grass recovered little more than one-tenth. Clover–grass ley recovered most fertiliser K, apparently taking up four-fifths of that applied. Potatoes, kale and permanent grass all recovered more than half of the fertiliser K given; cereals recovered least, although both responded well to K dressings.

Farmyard manure supplied large amounts of nutrients to all crops. Similar amounts of N, P and K appeared to be recovered from FYM whether or not NPK fertiliser was also used. A rough estimate was that crops such as kale, potatoes and permanent grass, which received FYM each year, recovered about 30 lb of N, 4 lb of P and 75 lb of K from a 10 tons/acre dressing.

Pedology Department

GENERAL PAPERS

3.1 GREENE, H. (1960) Paddy soils and rice production. A review. *Nature, Lond.* **186**, 511–513.

3.2 GREENE, H. (1961) Soil survey and land-use planning. *Span*, **4**, 151–153.

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3.3 GREENE, H. (1961) Some recent work on soils of the humid tropics. *Soils & Fert.* **24**, 325–327.

3.4 GREENE, H. (1963) Prospects in soil science. *J. Soil Sci.* **14**, 1–11. Presidential address to the Society, September 1962.

3.5 GREENE, H. (1963) *Soil science and soil surveys.* Contributed to Agenda item C.3.1. of the United Nations Conference on the application of science and technology for the benefit of the less developed areas.

RESEARCH PAPERS

3.6 (BROOME, J., ARCHER, R. K.), BURNETT, S. & LE RICHE, H. H. (1963) On some metallic constituents of leucocytes. *J. Histochem. Cytochem.* **11**, 446–447.

Relatively pure samples of equine leucocytes were analysed spectrochemically. Cu and Fe showed a pronounced increase from platelet to neutrophil, eosinophil and lymphocyte.

3.7 BROWN, G. & WEIR, A. H. (1963) The identity of rectorite and allevardite. *Proc. int. Clay Congr., Stockholm* **1**, 27–35.

Chemical analyses, cation-exchange measurements, X-ray examination, electron microscopy and infra-red absorption spectra show that rectorite and allevardite are the same mineral. The mineral is made up of pairs of dioctahedral 2 : 1-type layers. Alternate interlayers are mica-like and montmorillonite-like. The mica-like interlayers, which do not swell, contain about 1·7 univalent cations per unit cell layer; the montmorillonite-like interlayers, which swell, have about 0·7 univalent cations per unit cell layer. The name rectorite has priority over allevardite.

3.8 DERJAGUIN, B. V. & GREENE-KELLY, R. (1964) The birefringence of thin liquid films. *Trans. Faraday Soc.* **60**, 449–455.

Birefringence of oriented aggregates of Na-montmorillonite, expanded in sodium chloride solutions, were measured and compared with birefringences calculated from Wiener's equations. The difference between the calculated and observed values is nearly constant for swelling values of 10–20 times. It is inferred that the difference comes from the birefringence of the polymolecular water layers, and that it is evidence for a specific anisotropic structure. Anisotropy is also shown in some intercalacted organic polymolecular films.

3.9 LE RICHE, H. H. & WEIR, A. H. (1963) A method for studying trace elements in soil fractions. *J. Soil Sci.* **14**, 225–235.

Soils are divided into iron oxide, sand, silt and clay fractions, in forms suitable for trace-element analysis. The oxides are extracted by ammonium oxalate at pH 3·3, under ultra-violet irradiation; goethite and other iron oxides are dissolved, but gibbsite and boehmite are not affected. Some soil organic matter is extracted, and probably the trace elements with which this was associated are also dissolved.

Two horizons of two brown earths were analysed spectrochemically for Ba, Co, Cr, Cu, Ga, Mn, Ni, Pb, Sr, Ti, V and Zr. The extracted oxides were the fractions richest in trace elements, and contained large proportions of the total Co, Cu, Mn, Pb and V. Except for Sr, Ti and Zr, the amounts of trace elements in the sands were small and were distributed between the silicate-mineral fractions in the order: sand < silt < clay. About half the total Zr

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was in the sand fractions, but appreciable amounts were in the extracts and in the clays. Increases of iron oxide and clay in the illuvial B horizons were paralleled by increases in the amounts of Ba, Cr, Co, Ga, Ni and V.

3.10 STEPHEN, I. (1963) Bauxitic weathering at Mount Zomba, Nyasaland. *Clay Min. Bull.* **5**, 203–208.

Gibbsite, the dominant mineral in red and yellow earths from Mount Zomba in southern Nyasaland, is derived directly from orthoclase and acid plagioclase (albite-oligoclase). The bauxitisation apparently took place at an early stage in the history of the mountain. The evidence suggests that kaolinisation succeeds bauxitisation in the sequence of weathering, and that it is related to present-day weathering conditions.

Soil Microbiology Department

THESIS

4.1 DARBYSHIRE, J. F. (1963) A study of the initial stages of infection of clovers by nodule bacteria. Ph.D. Thesis, University of London.

GENERAL PAPER

4.2 JACKSON, R. M. (1964) Antibiosis and fungistasis of soil micro-organisms. *International Symposium on Factors determining the behaviour of Plant Pathogens in Soil.* Berkeley: University of California Press. (In the press.)

RESEARCH PAPERS

4.3 BROWN, M. E., BURLINGHAM, S. K. & JACKSON, R. M. (1964) Studies on Azotobacter species in soil. 3. The effects of artificial inoculation on crop yields. *Plant & Soil.* (In the press.)

The effect on plant growth of inoculating seeds, roots or soil with Azotobacter cultures was examined in pot and field experiments. Only plants inoculated with live untreated cultures that became established in the rhizosphere showed significant growth responses. In pot experiments inoculation increased yield by an average of 11%, leaf weight by 8% and root weight by 0·5%. These effects, which resemble those reported by Soviet and East European workers, were mostly not significant at the 10% level of probability. Azotobacter inoculation had most effect on plants grown in soil where disease or other conditions adversely affected growth. In an experiment on wheat in soil infected with *Ophiobolus graminis* significant improvements in the yield from Azotobacter inoculation was not correlated with a decrease in root disease.

Pot experiments showed that Azotobacter effects on yield were sometimes influenced by nitrogen but not other mineral fertilisers and by soil moisture but not by adding carbohydrates to the soil. In field experiments the size and age of the inoculum greatly affected response to inoculation.

4.4 COOPER, R. (1962) The retention of ^{32}P-labelled *Rhizobium* by legume seed after inoculation by vacuum treatment. *J. appl. Bact.* **25**, 232–236.

Legume seeds were vacuum-treated in a suspension of ^{32}P-labelled *Rhizobium meliloti* to find the numbers and uniformity of distribution of bacteria taken up and retained by the seeds after washing. Commercial seed retained 5–12 times as many bacteria as hand-harvested seed. From 5 to 15% of the seeds held 75–90%

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of the bacteria; vacuum treatment increased uptake by this small group of seeds by 60–300%, but had no significant effect on the majority that acquired relatively few bacteria. Therefore vacuum treatment of seeds during inoculation is likely to affect nodulation on a small proportion of the plants only.

4.5 GREGORY, P. H., LACEY, M. E., FESTENSTEIN, G. N. & SKINNER, F. A. (1963) Microbial and biochemical changes during the moulding of hay. *J. gen. Microbiol.* **33**, 147–174.

(For summary see No. 7.18.)

4.6 MOSSE, B. (1964) Electron microscope studies of nodule development in some clover species. *J. gen. Microbiol.* (In the press.)

Different stages of nodule development are described, and their possible significance in the host/symbiont relationship is discussed. The mature infection thread is surrounded by a wall continuous with that of the host cell, and a plant membrane continuous with the plasmalemma. Around the thread tip there is no wall and the plant membrane is fragmentary or absent. The infection thread contains a matrix in which bacteria are suspended, and with prolonged retention in the thread an electron-transparent region develops around each bacterium. When bacteria emerge from the infection thread they remain surrounded by an enclosing membrane formed as an extension of the existing thread membrane. Emergence from vesicles and characteristic thread protruberances is also illustrated. Until they emerge from the thread matrix and/or the electron-transparent zone surrounding them, there is little change in the structure of the bacteria. When released into host cytoplasm characteristic of an active meristematic cell the emerged bacteria divide, but in vacuolated dispersed cytoplasm characteristic of rapidly expanding cells they swell rapidly and do not divide. Finally, as the central vacuole is formed in the host cell, the plant membranes enclosing the bacteria become greatly distended and then the bacteria swell and assume their final bacteroid shape. The few remaining organelles of the host cytoplasm are compressed near the cell periphery.

The mature bacteroid has three membranes: an outer membrane of plant origin, a middle membrane—the original bacterial wall—and an inner cytoplasmic membrane, which also gives rise to interior vesicles. The ground cytoplasm of the bacteroid is very similar to that of the host cell, and the nuclear region consists of irregular electron-transparent and apparently discrete areas with little structure.

In two types of ineffective nodules examined the inability of bacteria and host to develop an effective symbiotic relationship appeared to be linked to advanced vacuolation and a scarcity of active cytoplasm in the host cells. In one there was also a pathogenic interaction between host and bacteria that led to breakdown of plant membranes and to bacterial lysis.

4.7 NUTMAN, P. S. (1964) The relation between nodule bacteria and the legume host in the rhizosphere and in the process of infection. *International Symposium on Factors determining the behaviour of Plant Pathogens in Soil.* Berkeley: University of California Press. (In the press.)

The small groups of root hairs that first become infected in the young clover seedlings are the centres from which infection of new hairs spreads up and down the root. Relative increase in number of infected hairs is constant until the first nodule develops, when hairs are infected much more slowly. Experiments on varying the number of seedlings growing together, and on preplanting, showed that this pattern is not affected by substances diffusable through

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the agar root medium and is probably endogenous in origin and controlled by substances moving from the plumule into the root. Removing the plumule (of *Trifolium fragiferum*) earlier than about 3 days, or later than about 5 days, lessens subsequent infection. Decapitation between 3 and 5 days sometimes greatly increases the number of infections. Infected hairs on seedlings decapitated early are less zoned and more concentrated near the root-tip. Excising root-tips at either 4 or 8 days has little influence on infection because tips rapidly regenerate. Results suggest that the top of the plant produces something that moves into the root, which is then activated to produce an infection-stimulating factor. That the infection-controlling system is not directly dependent on photosynthesis is indicated by the infection of seedlings grown in darkness; fewer hairs are infected than on plants grown in the light, but they show a similar discontinuous pattern.

4.8 (PEPYS, J., JENKINS, P. A.), FESTENSTEIN, G. N., GREGORY, P. H., LACEY, M. E. & SKINNER, F. A. (1963) Farmer's lung. Thermophilic actinomycetes as a source of "farmer's lung hay" antigen. *Lancet ii*, 607–611.

(For summary see No. 7.26.)

Botany Department

GENERAL PAPERS

5.1 WATSON, D. J. (1963) Climate, weather and plant yield. In: *Environmental control of plant growth*. ed. L. T. Evans. (Proceedings of a symposium held at Canberra, Australia, August 1962.) New York: Academic Press, pp. 337–350.

5.2 WATSON, D. J. (1963) Some features of crop nutrition. In: *The growth of the potato*. ed. J. D. Ivins and F. L. Milthorpe. (Proceedings of the 10th Easter School in agricultural science, Nottingham University.) London: Butterworth, pp. 233–247.

RESEARCH PAPERS

5.3 GOODMAN, P. J. (1963) Some effects of different soils on composition and growth of sugar beet. *J. Sci. Fd Agric.* **14**, 196–203.

Plants from plots of different soil type, with and without nitrogenous fertiliser, were harvested at 2–4-weekly intervals during 1960 and 1961 and analysed for N, P, K and Na. The uptake and distribution of the elements is discussed in relation to the yields obtained on the different soils. Yields were closely related to N-supply, though nitrogen application limited availability of P to roots. Losses, particularly of Na and K from roots, were found towards the end of the growth period.

5.4 HUMPHRIES, E. C. (1963) Effects of (2 chloro-ethyl)trimethylammonium chloride on plant growth, leaf area and net assimilation rate. *Ann. Bot., Lond.*, N.S. **27**, 517–532.

Both in glasshouse conditions and in a constant environment with light from fluorescent tubes, treatment with (2-chloro-ethyl) trimethylammonium chloride (CCC) increased the total leaf area of mustard plants. In the glasshouse the increase was caused by production of more lateral leaves, and in the growth

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cabinets by enlargement of stem leaves, as lateral branches did not form. The net assimilation rate was decreased, possibly by an effect of CCC on the photosynthetic mechanism or by more mutual shading of leaves, but more probably because the inhibition of stem growth by CCC decreased the demand for photosynthate and so caused the leaves to photosynthesise less.

Chlorophyll content, both per leaf and per unit area, and total dry matter per unit area, were increased in tobacco plants grown in culture solution containing CCC. The treatment affected the distribution of nitrogen, increasing the amount per leaf and decreasing it per stem.

5.5 HUMPHRIES, E. C. & FRENCH, S. A. W. (1963) The effects of nitrogen, phosphorus, potassium and gibberellic acid on leaf area and cell division in Majestic potato. *Ann. appl. Biol.* **52**, 149–162.

Potato plants in a factorial experiment with nitrogen, phosphorus and potassium were sprayed with gibberellic acid. Leaf areas were determined at 2-week intervals and cells in some leaves counted. Total leaf area of main-stem leaves was affected more by nitrogen than gibberellic acid. The effects of nitrogen and gibberellic acid on maximum size of main-stem leaves increased acropetally. Mineral nutrients affected lateral-stem leaves more than main-stem leaves, because laterals developed after the soil had been depleted of nutrients.

Leaf discs from main-stem leaves Nos. 7, 11 and 15 were macerated with pectinase and ethylene-diamine-tetracetic acid, and the cells counted. Cell size decreased from leaf to leaf up the stem. Gibberellic acid but none of the mineral nutrients increased cell size. Cell size accounts for only part of the increase in area caused by gibberellic acid, because cell number also increased.

In contrast to the effect in an earlier experiment, gibberellic acid increased dry matter of tubers, perhaps because larger pots were used. Potassium increased total dry matter and net assimilation rate.

In absence of nitrogen, gibberellic acid increased the leaf area duration, but this increase was not associated with increase in yield. With nitrogen most of the difference in leaf area duration caused by mineral nutrients was associated with lateral-stem leaves. Leaf area duration and dry matter yield were linearly related, and regression coefficients indicated that 1 g dry matter was produced by a leaf area duration of 3 or 4 dm^2 weeks.

5.6 HUMPHRIES, E. C. & FRENCH, S. A. W. (1963) The accuracy of the rating method for determining leaf area. *Ann. appl. Biol.* **52**, 193–198.

The errors involved in determining leaf area of intact potato plants by rating, i.e., by visual comparison with pictorial standards, are considered. The true area was consistently underestimated, but although the error in estimating areas of single leaves may be large, it is only about 7% for the total area of a large sample of leaves. Errors may arise from peculiarities in the standard pictures. The standards increased in size logarithmically, but further work is necessary to decide whether this is the best arrangement.

5.7 ORCHARD, B. (1963) Rapid estimation of amino-acids. *Nature, Lond.* **198**, 688.

The rate of appearance of a colour with ninhydrin is proportional to the concentration of amino-acid.

5.8 ORCHARD, B. (1963) A watering system for small plots. *J. agric. Engng Res.* **8**, 132–133.

An overhead sprayline is controlled to deliver a fixed volume of water at a number of fixed positions independent of water pressure or nozzle resistance changes.

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5.9 WELBANK, P. J. (1963) Toxin production during decay of *Agropyron repens* (couch grass) and other species. *Weed Res.* **3**, 205–214.

Inhibition of extension growth of rape seedlings was used to measure toxin production from plant material incubated with soil at 20° C. Waterlogging was most important for toxin production from *Agropyron repens* rhizome. It made little difference whether fresh, frozen or dried rhizome pieces were used. Toxicity was still increasing after 33 days' incubation. *A. repens*, *Agrostis tenuis*, *Lolium multiflorum* and *Medicago lupulina* all produced similar amounts of toxin per unit weight of dry matter in waterlogged mixtures with a sandy loam (pH 5·7) or a clay soil (pH 7·5). A medium loam (pH 7·2), which gave appreciable toxicity when incubated alone, produced slightly more toxicity from *Agrostis tenuis* and *Lolium multiflorum* than did the other soils, otherwise soil type had little effect. The results do not support the view that *Agropyron repens* is exceptional in producing toxin.

5.10 WELBANK, P. J. (1964) Competition for nitrogen and potassium in *Agropyron repens*. *Ann. Bot., Lond.* N.S. **28**, 1–16.

Stands of *Agropyron repens* (couch grass) and single young sugar-beet plants were grown in pots, separately and in competition, with nitrogen and potassium each supplied at three rates in a factorial design.

Competition decreased the relative growth rates and fresh-weight/dry-weight ratios of all parts of the sugar-beet plants and also their leaf area ratios and net assimilation rates. Both nitrogen and potassium increased relative growth rates of leaves and crowns of sugar beet and fresh-weight/dry-weight ratios; although these responses were usually curved, with little increase in effect between intermediate and high rates of either nutrient, only nitrogen greatly diminished the effects of competition, potassium diminished only its effect on relative growth rate of crowns.

Competition decreased nitrogen and potassium percentages in the leaves and uptake by the whole plant, but at high rates of nitrogen and potassium supply the decreases were small, suggesting that the amounts available were nearly adequate for both sugar beet and *A. repens*.

When total dry weights or leaf areas of sugar beet were compared with corresponding nutrient contents, variation in nitrogen alone could account for most of the effects of competition on growth, but potassium depletion probably also contributed a little. Net assimilation rate was correlated with potassium, but not nitrogen, per unit leaf area, but potassium differences could not adequately account for the effects of competition on net assimilation rate.

The apparently smaller effects of competition for potassium compared with competition for nitrogen, in spite of large responses to added potassium, may be the result of lower mobility of potassium in the soil.

5.11 WHEELER, A. W. (1963) Betaine: a plant-growth substance from sugar beet (*Beta vulgaris*). *J. exp. Bot.* **14**, 265–271.

Segments cut from chromatograms of the aqueous fraction of extracts of sugar-beet seed balls, leaves and roots, in the region giving a red-brown spot with iodine vapour similar in colour and *Rf* to that produced by betaine, inhibited growth in light of discs cut from primary leaves of dwarf French bean in a similar manner to betaine solutions. Similar regions from chromatograms of small amounts of aqueous fractions promoted growth of wheat coleoptile sections and cress hypocotyls, whereas larger amounts inhibited growth of the same tissues, and cress roots, as did betaine. Ethyl acetate fractions of the extracts had no effect on growth of bean leaf discs or cress seed-

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lings, but they inhibited germination of cress seeds and their subsequent growth, whereas water-soluble betaine did not affect germination of cress seeds.

Biochemistry Department

Thesis

6.1 Shah, S. F. H. (1963) Changes undergone by leaf lipids *in vitro*. Ph.D. Thesis, University of London.

General Papers

6.2 Holden, M. (1963) The purification and properties of chlorophyllase. *Photochem. Photobiol.* **2**, 175–180.

6.3 Pirie, N. W. (1963) The fundamentals of food-supply. *Lancet i*, 1411–1412.

6.4 Pirie, N. W. (1963) Human survival: the essential conditions. *Discovery*, **24**, 10–15.

6.5 Pirie, N. W. (1963) Speculation on the origins of viruses. *Medical News*, 12 April 1963, p. 9.

6.6 Pirie, N. W. (1963) Viruses, genes and cistrons. *Nature, Lond.* **197**, 568.

6.7 Pirie, N. W. (1964) The need for new thinking on food production. *Univ. Coll. Wales Agric. J.* (In the press.)

6.8 Pirie, N. W. (1964) The size of small organisms. *Proc. roy. Soc. B.* (In the press.)

Research Papers

6.9 Gregory, P. H., Lacey, M. E., Festenstein, G. N. & Skinner, F. A. (1963) Microbial and biochemical changes during the moulding of hay. *J. gen. Microbiol.* **33**, 147–174.

(For summary see No. 7.18.)

6.10 Harrison, B. D. & Pierpoint, W. S. (1963) The relation of polyphenoloxidase in leaf extracts to the instability of cucumber mosaic and other plant viruses. *J. gen. Microbiol.* **32**, 417–427.

(For summary see No. 7.20.)

6.11 Hill, J. M. & Mann, P. J. G. (1964) Further properties of the diamine oxidase of pea seedlings. *Biochem J.* (In the press.)

Pea-seedling diamine oxidase, a copper-containing enzyme, catalyses the oxidation of aliphatic monoamines and diamines, phenylalkylamines, histamine, spermidine, agmatine, lysine and ornithine. All these compounds react with the enzyme, under anaerobic conditions, to form yellow products; the pink colour of the enzyme is restored by oxygenation. Evidence was obtained that the yellow products are enzyme–substrate complexes and that the yellow colour comes from a copper complex. The copper-free protein was catalytically inactive; the activity towards all the substrates was restored by Cu^{2+}ions. The yellow complexes are unstable in presence of Cu^{2+}ions, but are stabilised by EDTA.

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6.12 (PEPYS, J., JENKINS, P. A.), FESTENSTEIN, G. N., GREGORY, P. H., LACEY, M. E. & SKINNER, F. A. (1963) Farmer's lung. Thermophilic actinomycetes as a source of "farmer's lung hay" antigen. *Lancet ii*, 607–611.

(For summary see No. 7.26.)

6.13 PIERPOINT, W. S. (1963) The distribution of succinate dehydrogenase and malate dehydrogenase among components of tobacco-leaf extracts. *Biochem. J.* **88**, 120–125.

1. The activities of succinate dehydrogenase, malate dehydrogenase and aconitate hydratase were measured on fractions of tobacco-leaf extracts prepared by differential centrifuging. The dehydrogenases were also measured in fractions produced when the chloroplast and mitochondrial preparations were resolved by sucrose gradient centrifuging into chloroplasts, chloroplast fragments and mitochondria.

2. All the succinate dehydrogenase of the extracts behaved as if it were attached to mitochondria. It sedimented along with the succinate–oxidase system, and the succinate–dehydrogenase activity was sufficient to account for its expected role in this oxidase system.

3. Most of the malate dehydrogenase was recovered in the supernatant fraction. The small proportions (5–19%) present in the mitochondrial and chloroplast preparations were reduced by washing. More enzyme appeared to be washed out of the chloroplasts and mitochondria as they sedimented in sucrose gradients.

4. Most of the aconitate–hydratase activity of leaf extracts was recovered in the supernatant fraction. The rest occurred in the mitochondrial fraction and could be partially removed by washing.

5. It is suggested that some of the malate dehydrogenase that was recovered in the supernatant fraction originated in chloroplasts and mitochondria, and that some of the aconitate hydratase originated in mitochondria.

6.14 PIERPOINT, W. S. & HARRISON, B. D. (1963) Copper-dependent and iron-dependent inactivations of cucumber mosaic virus by polyphenols. *J. gen. Microbiol.* **32**, 429–440.

(For summary see No. 7.27.)

Plant Pathology Department

BOOK

7.1 BAWDEN, F. C. (1964) *Plant viruses and virus diseases.* 4th edition. New York: Ronald Press Company, 356 pp.

GENERAL PAPERS

7.2 BAWDEN, F. C. (1964) Speculations on the origins and nature of viruses. In: *Plant Virology*. New York: Academic Press.

7.3 GREGORY, P. H. (1963) The spread of plant pathogens in air currents. *Advanc. Sci., Lond.* **19**, 481–488.

7.4 HARRISON, B. D. (1963) Virus du ringspot en Grande-Bretagne et leurs nématodes vecteurs. *Bull. off. int. Vin.* **36**, 307–318.

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7.5 KASSANIS, B. (1963) Interaction of viruses in plants. *Advanc. Virus Res.* **10**, 219–255.

7.6 KLECZKOWSKI, A. (1963) Protein of tobacco mosaic virus. *Biol. Rev.* **38**, 364–384.

RESEARCH PAPERS

7.7 BABOS, P. & KASSANIS, B. (1963) The behaviour of some tobacco necrosis virus strains in plants. *Virology* **20**, 498–506.

Strains of tobacco necrosis virus (TNV) differed in their behaviour when inoculated to French bean leaves kept at different temperatures. At 20° C strains A and D increased much faster than strain B. At 30° C strain A increased at about the same rate as at 20° C, but reached one-fourth the concentration attained at 20° C, whereas strains B and D reached hardly detectable amounts at 30° C. All strains infected less readily at 30° C than at 20° C, but the inhibition at 30° C differed with different strains and was least with strain A.

The strains were almost equally susceptible to inactivation by ultra-violet radiation *in vitro*. Tests *in vivo* were influenced greatly by the effect of UV on the capacity of the leaves to support virus multiplication. A method was devised that partly compensates for this effect. The corrected rate of inactivation of infective centres was similar to or a little less than the inactivation rate *in vitro*. The resistance of the infective centres of strains A, D and E remained constant for 2 hours after inoculation and then increased, whereas that of infective centres of strain B decreased 1 hour after inoculation and then increased faster than with the other strains.

The roots of some, but not all, species of plants growing in the same soils contained TNV. Strain A was the most prevalent, but as many as three strains were isolated from the roots of one plant. The leaves of normal-looking plants of some species also sometimes contain virus.

The fungicide captan delayed root infection of French bean and cucumber plants for 2–4 weeks. When virus was added to soil more infections occurred in sandy than in compost soils, and captan did not prevent infection. The results suggest that there may be two modes of transmission: by a captan-sensitive micro-organism and by mechanical injury of root cells against soil particles.

7.8 BABOS, P. & KASSANIS, B. (1963) Serological relationships and some properties of tobacco necrosis virus strains. *J. gen. Microbiol.* **32**, 135–144.

Isolates from seven virus stocks called tobacco necrosis were serologically related, but fell into two groups (serotypes) showing widely different degrees of serological relationship. Serotype A contained the five closely related strains A, B, C (Dutch cucumber necrosis virus), F and S (bean stipple-streak virus); and serotype D strains D and E. Strains A and F, isolated in Britain and the U.S.A. respectively, are possibly identical, but the others could be distinguished by the kinds of lesions caused in French bean, and C by the symptoms it causes in young cucumber plants. The virus particles of all strains were hexagonal in outline and of the same width. They had the same absorption spectrum and sedimentation constants, and all except strain B crystallised into rhombic plates. Only strain D failed to aid the multiplication of the satellite virus. It is proposed to restrict the name tobacco necrosis to viruses serologically related to what seems the commonest strain, namely, A.

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7.9 BABOS, P. & KASSANIS, B. (1963) Thermal inactivation of tobacco necrosis virus. *Virology* **20**, 490–497.

The thermal inactivation point of different strains of tobacco necrosis virus (TNV) in infective sap ranged between 85° C for strain B and 95° C for strains D and E. Determination of inactivation points and results of kinetic experiments place the six strains in the same order of susceptibility to heat.

TNV did not become inactivated exponentially at the same rate at all survival levels. The virus was inactivated at two different rates, as though it consisted of two components. At high temperatures the more resistant component was a small fraction of the total, but increased with decreasing temperature, and at about 40° C was the only one detectable. The inactivation rates of the two components differed greatly and increased with increases in temperature. The ratio of the two components and their inactivation rates at different temperatures differed with different strains. The changing ratio of the two components, and some other properties of the strains, show that the virus preparations were initially homogeneous and that the two components were produced by heating.

Nucleic acid extracted from strains A and E with phenol became inactivated similarly at 50° C to intact virus. Inactivation to 1% survival in water or acid buffers did not alter the antigenicity, sedimentation coefficient or the UV absorption spectrum of the virus. Also, there was no evidence that nucleic acid was released under these conditions.

7.10 BAILEY, L., GIBBS, A. J. & WOODS, R. D. (1963) Two viruses from adult honey bees (*Apis mellifera* Linnaeus). *Virology* **21**, 390–395.

(For summary see No. 11.11.)

7.11 BUXTON, E. W. & KENDRICK, J. B., Jr. (1963) A method of isolating *Pythium* spp. and *Fusarium oxysporum* from soil. *Ann. appl. Biol.* **51**, 215–221.

Weighed amounts of lightly pulverised soil were drawn through a perforated aluminium plate and impacted on agar media in Petri dishes, by placing the dishes in an Andersen air sampler, through which air was drawn at 14 l/min. The sampler was operated so that the soil was dispersed uniformly into 400 equally sized units/dish, each weighing 0·125 mg. These were transferred either to water–agar medium to detect *Pythium* spp. or to Dox–yeast–agar medium for *Fusarium oxysporum*. The amount of each fungus in the soil was estimated from the frequency it was recovered from the transferred soil units. Results were more reproducible than by the usual soil-dilution methods, and the method gave more uncontaminated cultures of Fusaria and Pythia.

7.12 (CALVERT, E. L.) & HARRISON, B. D. (1963) Outbreaks of tomato black ring virus in onion and leek crops in Northern Ireland. *Hort. Res.* **2**, 115–120.

Diseased onion and leek plants, often patchily distributed, occurred in several crops on light soils in one district, and tomato black ring virus was readily obtained from them by inoculating sap to tobacco. The virus from onion was indistinguishable in serological and plant-protection tests from the beet ringspot form of tomato black ring virus and differed from the lettuce ringspot form. The nematode *Longidorus elongatus* (de Man) was associated with disease outbreaks in onion and leek. Other crop and weed species were also found infected, and both the virus and its presumed vector, *L. elongatus*, apparently persisted through 4-year ryegrass/white clover leys.

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7.13 COCKBAIN, A. J., GIBBS, A. J. & HEATHCOTE, G. D. (1963) Some factors affecting the transmission of sugar-beet mosaic and pea mosaic viruses by *Aphis fabae* and *Myzus persicae*. *Ann. appl. Biol.* **52**, 133–143.

(For summary see No. 10.11.)

7.14 CORBAZ, R., GREGORY, P. H. & LACEY, M. E. (1963) Thermophilic and mesophilic actinomycetes in mouldy hay. *J. gen. Microbiol.* **32**, 449–455.

Actinomycetes isolated at 40° C and/or 60° C from mouldy hay included: *Micromonospora vulgaris* Waksman *et al.*, *Thermopolyspora polyspora* Hens., *T. glauca* sp. nov., *Streptomyces thermoviolaceus* Hens. *S. fradiae* (Waksman et Curtis) Waksman et Henrici, *S. griseoflavus* (Krainsky) Waksman et Henrici, *S. olivaceus* (Waksman) Waksman et Curtis and *S. griseus* (Krainsky) Waksman et Henrici.

7.15 GIBBS, A. J., KASSANIS, B., NIXON, H. L. & WOODS, R. D. (1963) The relationship between barley stripe mosaic and lychnis ringspot viruses. *Virology* **20**, 194–198.

Purified preparations of barley stripe mosaic and lychnis ringspot viruses contained similar rod-shaped particles. When shadowcast the particles had a model length of about 125 mμ and were 18–19 mμ wide. Negatively stained particles showed a central canal and a regular cross banding at 2·5-mμ intervals. The two viruses are distantly serologically related.

7.16 GIBBS, A. J., NIXON, H. L. & WOODS, R. D. (1963) Properties of purified preparations of lucerne mosaic virus. *Virology* **19**, 441–449.

Purified preparations of lucerne mosaic virus (LMV) contained bacilliform particles, which, mounted in neutral potassium phosphotungstate, were 18 mμ wide and of various lengths, though mostly 36 mμ, 48 mμ and 58 mμ long, with sedimentation constants (S_{20}) of 73, 89 and 99, respectively. Old preparations contained many particles 20–30 mμ long. Particles of all sizes contained about 17% nucleic acid, were serologically and electrophoretically indistinguishable and, except for the 20–30-mμ particles, seemed to be equally infective.

Negatively stained preparations showed evenly spaced knobs protruding from the surface of the particles; the arrangement of these knobs suggests that LMV has a structure quite unlike that of any plant virus so far described.

7.17 GREGORY, P. H. & LACEY, M. E. (1963) Liberation of spores from mouldy hay. *Trans. Brit. mycol. Soc.* **46**, 73–80.

Mouldy hay was shaken gently in a small wind-tunnel at various wind speeds and the concentration of the resulting dust-cloud determined by sampling with a cascade impactor. A wind of 1·2 m/sec removed 1,000 times as many spores from an obviously mouldy hay as from a well-made hay. Sampling at successive intervals during 1 hour while comparable samples of hay were being shaken at different wind speeds showed that the number of spores released per minute decreased rapidly from the start; two-thirds were removed in the first 3 minutes. Subsequent washing removed many more spores: the proportion of all the spores in the hay that could be blown away increased with increasing wind speed, from 2·5% at 0·6 m/sec to 15·5% at 4·9 m/sec. Although the total number of spores blown away in a given time is roughly proportional to wind speed, the decreases in liberation rate are similar in winds of 0·6, 1·2, 2·3 and 4·9 m/sec. Further, the curves for decrease in liberation rate with time for "total fungi", "total actinomycetes" and *Humicola lanuginosa* shaken

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from a mouldy hay associated with a case of farmer's lung hay were all similar.

Possibly relevant to the liberation of dry-spored fungi in nature is the observation that a sample of hay, which had already liberated 50 million spores/g dry weight while being blown for 31 minutes at 1·2 m/sec, produced a second typical cumulative liberation curve and liberated another 55 million spores when blown for another 31 minutes at 4·9 m/sec. This suggests the hypothesis that part of the mechanism of spore liberation by blowing away ("deflation") is that increasing the wind speed decreases the thickness of the boundary layer of air at the leaf surface, exposing more deeply immersed spores to the pruning action of eddies.

7.18 GREGORY, P. H., LACEY, M. E., FESTENSTEIN, G. N. & SKINNER, F. A. (1963) Microbial and biochemical changes during the moulding of hay. *J. gen. Microbiol.* **33**, 147–174.

Experimental batches of hay were baled at different moisture contents, and the microbial and biochemical changes studied by sequential sampling. The type of hay obtained could, in general, be related to the initial moisture content, and to the temperature subsequently attained. Good hays (*c.* 16% moisture) heated little and contained a small but diverse micro-flora. Hays baled at about 25% moisture heated to about 45° C and moulded, mainly with *Aspergillus glaucus*.

Wet bales, with initial moisture contents of about 40%, became very hot (60–65° C) and contained a large flora of thermophilic fungi, particularly *Aspergillus fumigatus*, *Absidia* spp., *Mucor pusillus*, *Humicola lanuginosa* and actinomycetes. During the initial heating period, which is correlated with a general rise in numbers of micro-organisms, particularly actinomycetes and bacteria, the acidity and volatile nitrogen increased. Later, when fungi and actinomycetes grew profusely, soluble sugars decreased rapidly and the pH rose to 7·0 or above.

Stacks of wet and dry hays were compared with *bales* made from the same hays. The wet stack developed a core of brown acid hay, containing many spore-forming bacteria but few fungi, surrounded by a layer of mouldy hay.

7.19 HARRISON, B. D., PEACHEY, J. E. & WINSLOW, R. D. (1963) The use of nematicides to control the spread of arabis mosaic virus by *Xiphinema diversicaudatum* (Micol.). *Ann. appl. Biol.* **52**, 243–255.

Field experiments on three soil types in southern Britain showed that applying dichloropropane-dichloropropene ("D.D") or methyl bromide at 2 lb/100 sq ft in summer killed over 99% of *X. diversicaudatum* in soil and almost stopped the infection of strawberry crops with arabis mosaic virus (AMV). Both chemicals killed *X. diversicaudatum* down to 28 in., the greatest depth sampled. "D.D" at 1 lb/100 sq ft gave variable results when applied in summer, but was more effective when left in the soil through the winter. At the doses used, dazomet, methyl isothiocyanate, metham-sodium, dibromochloropropane and tetramethyl thiuram disulphide killed too few *X. diversicaudatum* to control the spread of AMV.

Incidence of AMV in crops planted on treated land was closely related to the numbers of surviving *X. diversicaudatum*. Larvae and adults seemed equally susceptible to the chemicals. In some experiments other species of plant-parasitic nematodes were sometimes less affected by "D.D" than *X. diversicaudatum*.

In untreated soil planted with strawberries numbers of *X. diversicaudatum* tripled in 2 years, most of the increase coming in the second year. In "D.D"-

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treated soil the few survivors appeared to increase even more slowly than this. A nematicidal treatment that brings the *X. diversicaudatum* population to fewer than 1 nematode per 2 litres of soil should not need repeating for several years.

7.20 HARRISON, B. D. & PIERPOINT, W. S. (1963) The relation of polyphenoloxidase in leaf extracts to the instability of cucumber mosaic and other plant viruses. *J. gen. Microbiol.* **32**, 417–427.

Extracts made with buffered sodium diethyldithiocarbamate (DIECA) or potassium ethylxanthate from tobacco leaves infected with cucumber mosaic virus (CMV) were 5–500 times more infective than those made in buffer alone, or in buffer containing three other metal chelators which did not prevent the extracts going brown. DIECA preserved infectivity slightly better than did potassium ethylxanthate; both prevented browning equally. With DIECA in the extraction fluid, infectivity was not increased by other substances that enabled mitochondrial enzyme systems to be removed intact. CMV was inactivated by leaf polyphenols only when these were being oxidised. Oxidised polyphenols from virus-free leaves did not inactivate CMV when added together with copper, whereas deproteinised extracts of leaves crushed in an atmosphere of nitrogen did. When copper and chlorogenic acid, the main polyphenol in tobacco leaves, were added to infective extracts containing polyphenoloxidase the chlorogenic acid was oxidised and CMV was inactivated. A tobacco necrosis virus was slightly inactivated by incubating leaf extracts with chlorogenic acid and copper, but four other viruses were not. The tobacco necrosis virus was also the only one of these five to be at all stabilised by DIECA in the extraction fluid. The reported instability of some other plant viruses in leaf sap may mean that they also are susceptible to inactivation by polyphenol–oxidase systems.

7.21 HEATHCOTE, G. D. & WARD, J. (1963) The effect of DDT on *Myzus persicae* (Sulz.) and *Brevicoryne brassicae* (L.) (Aphidiae) in relation to the spread of cauliflower mosaic and cabbage black ring spot viruses. *Bull. ent. Res.* **53**, 779–784.

Insecticides, even systemic ones, fail to protect brassica seedlings from viruses transmitted by aphids. An explanation was sought through observations on how apterae and alates of *Myzus persicae* (Sulz.) were affected by contact with cauliflower leaves previously sprayed with a 0·2% DDT emulsion; contact for up to 30 minutes did not kill most of the aphids, but many were temporarily incapacitated; alatae of *Brevicoryne brassicae* (L.) were even less affected.

Apterae of *M. persicae* transmitted cauliflower mosaic virus (CIMV) and cabbage black ring spot virus (CBRSV) to sprayed seedlings, but did not transmit from infected plants sprayed with DDT. Alates of *M. persicae* occasionally transmitted CIMV from a sprayed infected plant to unsprayed plants but not to sprayed plants. These results support the idea that infection within seedbeds preponderantly results from the arrival from outside of already infective alates, and there is little spread within seedbeds.

7.22 HIRST, J. M. & STEDMAN, O. J. (1963) Dry liberation of fungus spores by raindrops. *J. gen. Microbiol.* **33**, 335–344.

Large transient increases in the concentration of some dry airborne spores coincident with the start of rain suggested that the first raindrops to wet surfaces might disperse spores other than in splash droplets or by wetting fructifications. Experimental collisions between glass beads or water drops and spore-bearing surfaces showed that both rapid air movement in advance of

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radially spreading splashes and vibration can suspend spores in air. Removal by air movement is most effective when large drops collide with surfaces carrying spores that are loose or raised above the surface.

7.23 KASSANIS, B. & WELKIE, G. W. (1963) The nature and behaviour of unstable variants of tobacco necrosis virus. *Virology*. **21**, 540–550.

Highly infective preparations of unstable variants of two strains of tobacco necrosis virus were prepared by grinding 1 g of infected leaf in 6 ml of 0·06*M* pH 8 phosphate buffer containing 25 mg bentonite per millilitre, and centrifuging the extracts at 10,000 rpm. The preparations remained infective for several hours at 19° C and had properties similar to nucleic acid extracted from the stable viruses with phenol: the infective centres caused by the unstable variants increased their resistance to ultra-violet radiation immediately after inoculation; in sucrose density gradients the infective particles sedimented as the nucleic acid, not as the intact virus; the variants were inactivated by pancreatic ribonuclease; extracting the unstable variants of either strain with phenol had little effect on infectivity, whereas extracting the stable viruses decreased it, more so with one strain than the other; in leaves infected with stable strains infective nucleic acid was detected before infective stable virus, and infectivity of extracts from leaves infected with unstable variants at first paralleled that of the nucleic acid from leaves infected with stable strains. It is concluded that the unstable variants occur in the leaves only as nucleic acid, which becomes inactivated when the leaves are extracted in conditions that allow inactivating enzymes to act.

7.24 KLECZKOWSKI, A. (1963) The inactivation of ribonucleic acid from tobacco mosaic virus by ultraviolet radiation at different wavelengths. *Photochem. Photobiol.* **2**, 497–501.

Although both thymine and uracil can form similar dimers, exposing RNA of tobacco mosaic virus to ultra-violet radiation of different wavelengths did not reproduce any of the phenomena that implicate dimerisation of thymine residues as a major cause of the inactivation of a bacterial transforming DNA. If uracil residues dimerise at all in the irradiated RNA such dimerisation either does not affect infectivity or is not photoreversible in the same way as dimerisation of thymine residues in DNA. Unlike inactivation of the transforming DNA, inactivation of the virus-RNA seems to be a function of the amount of absorbed radiation energy, irrespective of the wavelength within the range 285–230 mμ and irrespective of a change in the wavelength during irradiation.

7.25 (PADY, S. M.) & GREGORY, P. H. (1963) Numbers and viability of airborne hyphal fragments in England. *Trans. Brit. mycol. Soc.* **46**, 609–613.

Numbers and viability of airborne hyphal fragments were studied during July and August 1960, using silicone-coated and glycerine-coated slides in a cascade impactor. Hour-long samples were taken daily between 2 and 4 p.m. at approximately 1 m above the ground.

Hyphal fragments were caught every day, but in very different numbers; concentration averaged 126/m³ (range 10–599/m³). The hyphal pieces were mostly 20–40 μ long, but some were shorter than 10 μ and some longer than 100 μ. Dematiaceous fragments were more numerous than hyaline ones. Conidiophores, especially the terminal portion, were abundant.

Fragments gave rise to a germ tube from one or both ends of the hypha. Frequently the germ tube developed into a short conidiophore which often produced spores. Percentage germination was 1–43 on silicone slides (average

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16·2). Germination of *Cladosporium* spores on the same slides was 16–90 (average 62)%. On glycerine jelly germination was irregular, with hyphae averaging 8·6 and *Cladosporium* spores 46%.

7.26 (PEPYS, J.), (JENKINS, P. A.), FESTENSTEIN, G. N., GREGORY, P. H., LACEY, M. E. & SKINNER, F. A. (1963) Farmer's lung. Thermophilic actinomycetes as a source of "farmer's lung hay" antigen. *Lancet ii*, 607–611.

Mouldy hay was produced in the laboratory by sterilising good hay, inoculating with aqueous suspensions of micro-organisms and incubating at 40° or 60° C. Extracts were tested for presence of farmer's lung hay antigen by agar-gel double-diffusion and immunoelectrophoresis tests against sixteen to twenty sera from patients with farmer's lung.

Farmer's lung hay antigen developed in hay after: (1) inoculating with mixed microbial suspensions from antigenically active hay; (2) inoculation with mixed suspensions of pure cultures of thermophilic actinomycetes, after raising the pH of the hay to 7·0 either by inoculation with fungi or by infiltration with ammonia vapour; and (3) inoculation at pH 7·0 with pure cultures of *Thermopolyspora polyspora* or with *Micromonospora vulgaris*.

Farmer's lung hay antigen did not develop in hay inoculated with fungi only, or with six other actinomycetes tested, or after heating (though some sera reacted to fungal antigens in all these extracts).

T. polyspora is the richest source yet found of farmer's lung hay antigen, and inhalation of an extract by affected subjects produces some of the features of farmer's lung. Pure cultures can produce farmer's lung hay antigen on artificial media without hay. Spores and mycelium are rich in farmer's lung hay antigen, and inhalation of the spores may play a part in farmer's lung disease. Other antigens relevant to farmer's lung may be found in other actinomycetes, not yet cultured.

7.27 PIERPOINT, W. S. & HARRISON, B. D. (1963) Copper-dependent and iron-dependent inactivations of cucumber mosaic virus by polyphenols. *J. gen. Microbiol.* **32**, 429–440.

Extracts made by crushing infected tobacco leaves in buffer solution containing sodium diethyldithiocarbamate (DIECA), centrifuging at 8,000 g and dialysing the supernatant fluids against dilute buffer, were used to study the inactivation of cucumber mosaic virus (CMV). Incubating such extracts with chlorogenic acid and copper inactivated them; inactivation was usually much less when they were incubated with chlorogenic acid alone. Inactivation did not occur *in vacuo* or when DIECA was added. DIECA did not reactivate inactivated virus. CMV was inactivated rapidly by incubating with caffeic acid and copper, and slowly with catechol and copper, but not with five other phenols. The end-products of oxidation formed when chlorogenic acid was incubated with extracts of uninfected leaves did not inactivate CMV. Some features of the CMV-inactivating system are explained by the properties of tobacco-leaf polyphenoloxidase. The compounds most effective in preserving the infectivity of CMV during extraction from leaves, DIECA and potassium ethylxanthate, are those which most strongly inhibit the enzyme. Conversely, the polyphenols that inactivate CMV *in vitro* are those oxidised most rapidly. Inconsistent effects of copper on the *in vitro* inactivating system can be partly explained by the different copper requirement of the polyphenoloxidase in extracts from plants infected for different times. Iron salts also accelerate the inactivation of CMV by chlorogenic acid. The process requires air and is prevented by DIECA; iron did not reactivate the DIECA-inhibited polyphenoloxidase. This system

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seems different from the one stimulated by copper. The concentration of iron in leaf extracts is usually less than that needed by the inactivating system.

7.28 SLOPE, D. B. (1962) Cephalosporium stripe disease of wheat. *Plant Path.* **11**, 160.

Reports the first record of Cephalosporium stripe of wheat in England, with descriptions of symptoms and methods used in pathogenicity tests.

7.29 SLOPE, D. B. & (LAST, F. T.) (1963) Effects of some chlorinated hydrocarbons on the development of take-all of wheat. *Plant Path.* **12**, 37–39.

Aldrin, dieldrin, chlordane and heptachlor mixed with soil decreased the severity of take-all of wheat grown in pots. Heptachlor did so most; when mixed with soil at a rate equivalent to broadcasting about 18 lb of active ingredient per acre, it decreased the proportion of infected seminal roots from 96 to 37%, and that of infected crown roots from 66 to 2%. At this rate of application thiram, a standard fungicide, did not affect disease development.

7.30 WATSON, M. A. and SERJEANT, E. P. (1964) The effect of motley dwarf virus on yield of carrots and its transmission in the field by *Cavariella aegopodiae* Scop. *Ann. appl. Biol.* **53**, 77–93.

In 1959 and 1961, when the willow–carrot aphid, *Cavariella aegopodiae*, infested carrots at Rothamsted and Woburn early and severely, crops were infected with motley dwarf virus in late May or early June and yielded about 6 tons of roots/acre. In 1962, when invasion was late and sparse, the crops remained almost uninfected and yielded 24–25 tons/acre. In 1960, when aphids invaded early but multiplied slowly, about 85% of carrots on unsprayed plots became infected in July and August, and the yield was 9·2 tons/acre. Spraying three times with "Metasystox" starting at an early stage of growth affected yield little in 1961, or in 1962, but increased yield by about 3 tons/acre in 1960.

Field-plots experimentally infected in 1962 by aphids fed on infected plants in the glasshouse lost 11 tons/acre from infection in early June, 8 tons/acre from infection in late June and 6 tons/acre from infection in July. Plots infested with virus-free aphids in early June yielded as much as uninfested plots. Experimental infection did not affect yield in 1959 and 1961, for the crop was naturally infected before the experiment began.

The yields in different years were linearly related to the log mean weekly numbers of *C. aegopodiae* caught on sticky traps near the sites, and the regression accounted for much of the variance in yield. The residuals of the log mean weekly trap counts were negatively related to residual weekly rainfall in inches; 1 in. of rain above average approximately halved the increase in aphids. This may explain the failure of early invading aphids to become numerous at Woburn in 1960, when an inch of rain fell in three consecutive weeks in June.

Treating seed or seedlings with systemic insecticide did not prevent young plants from becoming infected when infective aphids were cultured on them 10–14 days after treatment.

Aphids taken from willow in the spring did not transmit motley dwarf to carrots, but did so after they had fed on infected carrots. Aphids from wild umbellifers often transmitted motley dwarf to carrots.

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Nematology Department

Book

8.1 WALLACE, H. R. (1963) *The biology of plant parasitic nematodes.* London: Edward Arnold, viii 280 pp.

This book, the first of its kind, on plant parasitic nematodes, summarises current knowledge of various aspects of their biology, including reproduction, development, growth, the soil environment, movement, behaviour, host–parasite relations and populations. It also indicates major gaps in knowledge, discusses critically some accepted hypotheses and suggests some underlying principles indicated by experimental work.

Theses

8.2 RAO, G. N. (1963) Studies on the assessment of the nematicidal actions of chemical soil sterilants against the potato-root eelworm (*Heterodera rostochiensis* Woll.). Ph.D. Thesis, London University.

8.3 HOOPER, D. J. (1963) Some contributions to the study of plant and soil nematodes. Thesis for Membership of the Institute of Biology, London.

General Papers

8.4 ANON. (1963) The soil sterilant and nematicide group. *Nature, Lond.* **198**, 1048.

8.5 PEACHEY, J. E. (1963) Chemical control of plant-parasitic nematodes in the United Kingdom. *Chem. & Ind.* 1736–1740.

8.6 PEACHEY, J. E. (1964) Progress in chemical soil sterilisation. *Proceedings of the 2nd British Insecticide & Fungicide Conference, Brighton* 1963. (In the press.)

8.7 (SOUTHEY, J. E.) (1964) Plant nematology. *Tech. Bull. Minist. Agric., Lond.* No. 7. (Revised edition with articles by M. T. Franklin, J. B. Goodey, F. G. W. Jones, A. M. Shepherd, J. E. Peachey and H. R. Wallace.)

Research Papers

8.8 FRANKLIN, M. T. (1963) Antirrhinum not a host of *Heterodera rostochiensis*. *Nematologica* **9**, 301.

8.9 GASSER, J. K. R. & PEACHEY, J. E. (1964) A note on the effects of some soil sterilants on the mineralisation and nitrification of soil nitrogen. *J. Sci. Fd Agric.* **15**. (In the press.)

Dazomet, dichloropropane-dichloropropene, metham-sodium and methyl isothiocyanate were applied to seven glasshouse and four field soils, and methyl bromide applied to two field soils. In both glasshouse and field all sterilants retarded nitrification of ammonium-nitrogen, and in some soils increased the mineralisation of soil organic-nitrogen. Dazomet had most effect and metham-sodium least. In field soils methyl bromide increased the mineralisation of soil organic-nitrogen more than twice as much as other sterilants.

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8.10 (GERAERT, E.) & GOODEY, J. B. (1963) The priority of *Tylenchus hexalineatus* over *T. megacephalus*. *Nematologica* **9**, 471.

8.11 GOODEY, J. B. (1963) Speculations on the identity of the parts of the Tylenchid spear. *Nematologica* **9**, 468–470.

It is suggested that the spear guiding apparatus consists of the cheilostom, prostom and mesostom; that the shaft of the spear is the fused metarhabdions, the knobs the fused telorhabdions and the conical anterior end the fused metarhabdial teeth.

8.12 GOODEY, J. B. & HOOPER, D. J. (1963) The nerve rings of *Longidorus* and *Xiphinema*. *Nematologica* **9**, 303–304.

Two nerve rings, about a body width apart, are recorded for *Xiphinema diversicaudatum*, *X. index*, *Longidorus elongatus* and *L. maximus*. A hemizonid was associated with the anterior ring and a hemizonion with the posterior ring in some species.

8.13 HARRISON, B. D., PEACHEY, J. E. & WINSLOW, R. D. (1963) The use of nematicides to control the spread of arabis mosaic virus by *Xiphinema diversicaudatum* (Micol.). *Ann. appl. Biol.* **52**, 243–255.

(For summary see No. 7.19.)

8.14 HOOPER, D. J. (1963) *Trichodorus viruliferus* n.sp. (Nematoda: Dorylaimida). *Nematologica* **9**, 200–204.

Trichodorus viruliferus n.sp., ♂ and ♀ described from a light sandy English soil. It is distinguished from *T. primitivus* (de Man, 1880) Micoletzky, 1922 and *T. similis* Seinhorst, 1963 by the shape of the spicules and gubernaculum in the male and by the shape, in lateral view, of the cutinised pieces at the vulva and the shape of the vagina in the female. It is a virus vector and has also been reported from several localities in Holland and from Germany.

8.15 (LUC, M.) & GOODEY, J. B. (1963) *Hirschmaniella* nom. nov. for *Hirschmannia*. *Nematologica* **9**, 471.

Hirschmannia is preoccupied by a Crustacean.

8.16 RAO, G. N. & PEACHEY, J. E. (1964) Chemical soil sterilisation: estimating kill of potato-root eelworm. *Exp. Hort.* No. 11. (In the press.)

The two most accurate and convenient methods for estimating numbers of potato cyst-nematodes killed by chemical sterilisation of soil were by counting either eggs and larvae which remained unstained after soaking cysts in New blue R stain or by counting larvae recovered from macerated roots of potato plants grown for 6 weeks at 19° C in pots of field soil.

8.17 SHEPHERD, A. M. (1963) The emergence of larvae of *Heterodera goettingiana* Liebs *in vitro* and a comparison between field populations of *H. gottingiana* and *H. rostochiensis* Woll. *Nematologica* **9**, 143–151.

Of many treatments tried in an attempt to get larvae of *H. goettingiana* to hatch *in vitro*, only soaking cysts in calcium hypochlorite solution was effective, giving a 30% hatch. Comparing the behaviour of populations of *H. goettingiana* and *H. rostochiensis* in field plots with host and non-host crops, and in fallow soil, showed that *H. goettingiana*, like *H. rostochiensis*, is stimulated to hatch by a host crop. A larger proportion of hatched larvae of *H. goettingiana* entered host roots than those of *H. rostochiensis*.

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8.18 SIDDIQI, M. R. & GOODEY, J. B. (1963) The status of the genera and sub-families of the Criconematidae (Nematodea); with a comment on the position of *Fergusobia*. *Nematologica* **9**, 363–377.

Caloosia n.g. is erected to contain *Hemicycliophora longicaudata* Loos, 1948 (type) and *C. paralongicaudata* nom. nov., syn. *H. longicaudata* of Siddiqi, 1961.

Hemicriconemoides strictathecatus Esser, 1960 has anteriorly-concave spear knobs and thus *Hemicriconemoides* together with *Criconema* and *Criconemoides* constitutes the Criconematinae.

Paratylenchidae is not recognised as a family and *Gracilacus* Raski, 1962 is reduced to synonomy with *Paratylenchus*, a group in which the basal knobs of the spear are spheroid and slope backwards.

Hemicycliophora and *Caloosia* are placed in Hemicycliophorinae Skarbilovich, 1959.

The male of *Iota squamosum* Cobb, 1913 seems to belong to *Hemicriconemoides*, with *H. mangiferae* Siddiqi, 1961 and *H. strictathecatus* Esser, 1960 as synonyms.

Criconema is probably a genus without males.

Macroposthonia seems to be most closely related to *Criconemoides*.

Fergusobia is removed from the Allantonemantidae and is placed within the Fergusobidae n. fam. close to the Criconematidae.

8.19 WALLACE, H. R. & DONCASTER, C. C. (1964) A comparative study of the movement of some microphagous, plant parasitic- and animal-parasitic nematodes. *Parasitology*. (In the press.)

Ciné film and direct observation showed that microphagous, plant and animal nematodes have the same basic wave pattern when moving. Their speed is linearly related to the product of their length and wave frequency during unrestricted movement in deep water. The speed, wave pattern and frequency of the plant nematode *Ditylenchus dipsaci* and the animal nematode *Trichostrongylus colubriformis* changed in a similar way in response to changes in water film thickness on the surface of agar of different concentrations. *T. colubriformis* like *D. dipsaci* were most mobile in a sand–water medium at a suction corresponding to the stage when most of the water has drained from the pores. The optimum temperature for activity of *T. colubriformis* and *D. dipsaci* was about 20° C and both survived desiccation at 50% relative humidity and 24° C for 32 days. *T. colubriformis* was attracted to and aggregated around grass roots (*Phleum pratense*). The results suggest that the free-living stages of microphagous, plant-parasitic and animal-parasitic nematodes move similarly and that nematodes can be divided arbitrarily into three groups: (1) those active enough to swim in deep water; (2) those able to swim in thick water films, escape from the soil and ascend plants above ground level; and (3) those too inactive to swim, the crawlers, which are largely confined to the soil. The habitat of free-living stages of nematodes, irrespective of their host or feeding habits, is probably related to their propulsive power.

8.20 (WILLIAMS, J. R.) & GOODEY, J. B. (1963) Deposition of type slides at Rothamsted. *Nematologica* **9**, 300.

Type slides of nematodes described by Williams between 1958 and 1960 from Mauritius are now in the slide collection at Rothamsted.

8.21 WINSLOW, R. D. (1964) Soil nematode population studies 1. Migratory root-Tylenchida and other nematodes of the Rothamsted and Woburn six-course rotations. *Paedobiologia*. (In the press.)

The nematode fauna in the top 15-cm layer of soil in two rotational experiments was examined periodically during 1958, 1959 and 1960, using a modified

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Baermann technique. One experiment was sited on sandy soil near Woburn, Bedfordshire, the other on flinty clay-loam at Rothamsted. In both soils numbers of total nematodes and of Tylenchida showed strong seasonal rhythm with minima in May, June or July and maxima in late summer or autumn. Soil type seemed more important than crop in determining presence or absence of certain migratory root nematodes. Within each soil type the crop affected the prevalence of these nematodes, cereals usually supporting more than the row crops, sugar beet and potatoes.

Migratory Tylenchida found belonged mainly to the genera *Pratylenchus*, *Paratylenchus*, *Tylenchorhynchus* and the spiral nematodes (*Rotylenchus*, *Helicotylenchus*), although the last-mentioned were scarce at Woburn. A few *Criconemoides* were found in both soils and small numbers of *Hemicycliophora* at Woburn. Of the remaining Tylenchoidea, *Tylenchus* was the dominant genus, with fewer *Psilenchus*, *Ditylenchus*, neotylenchs, and larvae of *Heterodera*. Aphelenchoidea present were mainly *Aphelenchus* and *Aphelenchoides*. The migratory Dorylaimoidea were represented by a few *Longidorus* and *Trichodorus*.

Insecticides and Fungicides Department

General Papers

9.1 Elliott, M. (1963) Pyrethrolone. *Jap. J. Pharm. Chem.* **33**, 824–833.

9.2 Potter, C. (1963) Factors influencing the biological efficiency and persistence of insecticides. *Proc. 2nd Brit. Insect. Fung. Conf. Brighton* (1963).

9.3 Sawicki, R. M. (1963) Some general considerations on house-fly rearing techniques. *W.H.O. Symposium on culture procedures for arthropod vectors and their biological control agents. EBL/Working Paper* no. 17/63.

9.4 Stevenson, J. H. (1963) Pyrethrum: its use in public health. *R. Soc. Health J.* **83**, 207–211.

Research Papers

9.5 Bardner, R. (1963) Some systemic insecticides compared as seed treatments against aphids. *Plant Path.* **12**, 72–79.

In glasshouse tests 13 insecticides (American Cyanamid 18133, Bayer 4536, demeton, demeton-methyl, "Disyston", dimethoate, "Isolan", menazon, morphothion, phorate, phosphamidon, schradan, "Trithion") were applied as slurry seed dressings to wheat, kale and sugar-beet seeds. Rates of application in g insecticide per 100 g of seed were: wheat 0·40 and 0·20, kale 4·00 and 2·00, sugar beet 0·88 and 0·44. Insecticidal activity was measured by caging aphids on the plants. Aphids used were *Rhopalosiphum padi* L. on wheat, *Brevicoryne brassicae* L. on kale and *Aphis fabae* Scop. on sugar beet. The maximum period for which aphids were all killed was about 40 days, though the numbers of aphids were decreased for another 10–30 days. The insecticides differed considerably in toxicity and persistence. Dimethoate was the most persistent and the most toxic, but demeton, "Disyston" and phorate were also good. "Isolan", tested only on kale, was very toxic and persistent. Menazon and 18133, which were persistent but not very toxic, would have probably been more effective at higher rates. Schradan and "Trithion" were ineffective. Other insecticides were intermediate in performance.

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9.6 (BROADBENT, L.), BURT, P. E. & HEATHCOTE, G. D. (1964) Home-production of seed for early potatoes. 6. Insecticides applied to the soil or tubers. *Exp. Hort.* **11**. (In the press.)

The systemic insecticides dimethoate, disulfoton, menazon and phorate applied in the soil as granular formulations before potato tubers were planted, and menazon applied directly to the tubers, kept the plants almost free from aphids for several weeks after the foliage emerged, and prevented or greatly limited the spread of leaf roll virus. In a year when leaf roll spread more than usual, disulfoton and phorate were most effective in checking spread. The spread of virus Y was occasionally checked, but incidence was seldom less than half that in untreated plots.

Such undesirable side effects as crop damage, loss of yield and the presence of residues in the tubers were negligible at the rates at which the insecticides were applied.

This method of controlling aphids and virus diseases is better than the frequent spraying of the foliage with insecticides because it costs no more and damages the crop less.

9.7 LAST F. T. (1963) Effect of temperature on cereal powdery mildews. *Plant Path.* **12**, 132–133.

Increasing post-inoculation temperatures progressively decreased the time for mildew pustules to appear from 13 days at 5° C to 3 days at 18° C. Pustules developed at similar rates between 18° and 25° C.

9.8 LORD, K. A., MOLLOY, F. M. & POTTER, C. (1963) Penetration of diazoxon and acetyl choline into the thoracic ganglia in susceptible and resistant house-flies and the effects of fixatives. *Bull. ent. Res.* **54**, 189–197.

The nerve sheath of the thoracic ganglion of the house-fly (*Musca domestica* L.) is readily permeable to diazoxon but is impermeable to acetyl choline and acetyl thiocholine. Acetone and other lipoidal solvents, but not formaldehyde, were found to destroy the barrier to entry of the substrates, acetyl choline and acetyl thiocholine, and it is inferred that the barrier is lipoidal. At −16° C acetone does not destroy the cholinesterase of the ganglion.

Cholinesterase associated with the ganglion could be divided into three regions which showed different inhibition characteristics: (*a*) "superficial" enzyme outside the nerve sheath, inhibited by $3{\cdot}3 \times 10^{-8}$ *M* diazoxon; (*b*) "peripheral" enzyme in the cellular region of the ganglion, inhibited by $3{\cdot}3 \times 10^{-8}$ *M* and $3{\cdot}3 \times 10^{-9}$ *M* diazoxon; (*c*) "central" enzyme in the synaptic area, inhibited by not less than $3{\cdot}3 \times 10^{-7}$ *M* diazoxon. Using inhibition of cholinesterase as an indicator of penetration, no difference in permeability was found between the ganglia of the susceptible and resistant strains. No difference was found in the inhibition of cholinesterase by diazoxon in the ganglia of susceptible and resistant strains.

It is concluded that, if inhibition of cholinesterase of the nervous system is the cause of death, differences between susceptible and resistant strains that affect resistance do not lie in the ganglia; also, that inhibition of cholinesterase in the thoracic ganglion is unlikely to be the cause of death.

9.9 MCINTOSH, A. H. (1963) Some formulations of fungicides for control of potato blight. *Proc. 2nd Brit. Insect. Fung. Conf. Brighton* (1963), Paper X-2.

For bioassay, detached potato leaflets are sprayed with fungicide, "rain" washed, sprayed with a suspension of sporangia and, later, assessed for in-

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fection. Copper oxychloride suspensions, formulated with either 1% paraffin wax emulsion or with 0·1% sodium thiobenzoate, performed about 10 times better in this test than a commercial wettable powder. However, the corresponding improvement for fentin acetate, formulated with 1% paraffin wax emulsion, was only about 2 times.

Field trials in 1962 showed that copper oxychloride–wax formulations usually gave larger yields than the wettable powder formulation.

9.10 PHILLIPS, F. T. (1963) The application and measurement of labelled residual insecticides in some physico-chemical studies. *Proceedings of Symposium on Radiation and Radioisotopes applied to insects of agricultural importance. Athens* (*April* 1963) *International Atomic Energy Agency, Vienna.*

The disappearance of residual films of insecticides from plant and other surfaces can be conveniently studied by labelling the insecticide with a radioisotope of sufficient radiant energy to allow for a simple measuring technique.

Methods of application of insecticide solutions on different surfaces led to the design and construction of a spray chamber suitable for distributing very small amounts (a few drops) of radioactive liquid formulations over a 35-cm² circular area. The apparatus is described together with tests of its efficiency.

The rates at which Cl^{36}-labelled dieldrin and aldrin crystals volatilise from glass surfaces are reported.

Entomology Department

THESIS

10.1 EL IMAM EL KHIDIR MOHAMED NOUR. (1963) Ecological studies on *Aleyrodes brassicae* with special reference to dispersal. Ph.D. Thesis, University of London.

GENERAL PAPERS

10.2 BANKS, C. J. (1964) Feeding and excretion behaviour of aphids. *Anim. Behav.* **11**, 604.

10.3 COCKBAIN, A. J. (1964) Probing and feeding behaviour of alate aphids in relation to the transmission of some plant viruses. *Anim. Behav.* **11**, 603.

10.4 DOBSON, R. M. (1962) Marking techniques and their application to the study of small terrestrial animals. In: *Progress in Soil Zoology I*, ed. P. W. Murphy. London: Butterworths, 228–239.

10.5 EDWARDS, C. A. (1964) Persistence of insecticides in the soil. *New Sci.* **19**, 282–284.

10.6 GERARD, B. M. (1964) Lumbricidae (Annelids); Synopsis of the British Worms. *Synopses of the British Fauna:* No. 6. 2nd Edit.

10.7 JOHNSON, C. G. (1963) The aerial migration of insects. *Sci. Amer.* **209**, 132–138.

10.8 JOHNSON, C. G. (1963) The origin of flight in insects. *Proc. R. ent. Soc. Lond.* **28**, 26–27.

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10.9 LEWIS, T. & TAYLOR, L. R. (1963) Factors affecting insect flight times. *New Sci.* **18**, 584.

RESEARCH PAPERS

10.10 BANKS, C. J. & MACAULAY, E. D. M. (1964) The feeding, growth and reproduction of *Aphis fabae* Scop. on *Vicia faba* under experimental conditions. *Ann. appl. Biol.* **53**. (In the press.)

The total amount of sap ingested by individual larvae and adult (apterous virginoparae) of *Aphis fabae* on field beans, in constant light and temperature and high air humidity, was estimated by adding the weights of honeydew excreted and of water lost by evaporation to increase in body weight during growth and to the weight of larvae born throughout the lives of the adult insects. The quantity of respiratory gases was ignored. The excreta of 10 individual aphids was collected automatically and continuously from birth to death. Honeydew was also collected daily in mineral oil from other aphids of the same age on similar plants to estimate the size of the droplets. The reproductive rate, fecundity and length of reproductive and post-reproductive life of the adult aphids were also recorded.

The total sap ingested by the larva was about 3·5–4·5 mg in a life of 7 days. During the reproductive life of 21 days, the adult ingested about 30 mg of sap, or about 90% of the total of both larva and adult together; only about 10% was used for growth and reproduction.

The excretion of the adult rose to a maximum of 30–40 drops per day on the third day of adult life; the rate then declined, apparently because of changes within the aphid itself and not within the plant, for when the insects were transferred to fresh plants the excretion continued to decrease. The rate of feeding, which is about equal to the rate of excretion, therefore also decreased as the insect aged, but its rate of reproduction remained fairly steady for about 16 days. The swelling of the abdomen and the slight increase in weight during the post-reproductive life of about 2 weeks suggested that, although excretion had stopped, small amounts of sap continued to be ingested. The aphids ingested about the same amount of sap from two varieties of field bean but were significantly more fecund on one than on the other, a difference probably attributable to differences in the quality of the sap of the two varieties.

10.11 COCKBAIN, A. J., GIBBS, A. J. & HEATHCOTE, G. D. (1963) Some factors affecting the transmission of sugar beet mosaic and pea mosaic viruses by *Aphis fabae* and *Myzus persicae*. *Ann. appl. Biol.* **52**, 133–143.

Alate *Aphis fabae* were often less efficient vectors than *Myzus persicae* of pea mosaic virus and sugar-beet mosaic virus. Flight-mature *A. fabae* rarely transmitted these viruses unless they had either flown (tethered) or fasted for several hours before feeding on infected plants; by contrast, flight-mature *M. persicae* transmitted either virus before flying or fasting, though more frequently afterwards than before. There was little difference in the infectivity of the two species after they had flown and then fed for a short time on infected plants.

Aphids flown for 1–5 hours and then allowed a short feed on infected plants transmitted only slightly more often than aphids flown for 15 minutes, but they remained on the host plants longer. After flying for 15–60 minutes, many *A. fabae* settle permanently on broad bean plants, and a few on sugar-beet plants, but most *M. persicae* flew off after feeding on these plants for a few hours.

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Many flight-mature alatae of both species probed briefly before flying from a plant for the first time; more *M. persicae* than *A. fabae* transmitted after such pre-flight probing on infected plants.

The infectivity of flying or fasting alatae, and fasting apterae, decreased at similar rates. The rate of decrease was accelerated as the temperature rose, and few aphids transmitted after 30 minutes at temperatures above 30° C.

PMV and SBMV, but not henbane mosaic virus, were transmitted more often by alatae than by apterae. The species of plant (broad bean or sugar beet) on which aphids developed did not affect their ability to transmit PMV or SBMV.

10.12 DOBSON, R. M. (1962) Observations on the intermittent flight activity of the male wheat-bulb fly, *Leptohylemyia coarctata* (Fall.) *Ent. mon. Mag.* **98**, 75–79.

Male wheat-bulb flies, *Leptohylemyia coarctata* (Fall.), often made short repeated flights just above the ears of the crop. This activity occurred in many different types of weather, and first appeared when maturing females, ready for copulation, became common. It occurred only after 11.30 hours G.M.T. and was exhibited by solitary flies and by groups of flies moving together. Some flies were active more often than would have been expected if they had appeared at random from the population, and these exceptionally active individuals lived longer than others. Activity caused flies to band together in small groups, and the mutual stimulation increased the total activity of the male population greatly. Its possible role in the formation of large aggregations and its effects on mating efficiency are discussed.

10.13 EDWARDS, C. A. (1964) The bionomics of Swift moths. I. The Ghost moth *Hepialus humuli* L. *Bull. ent. Res.* **55**. (In the press.)

Two polyphagous species of Swift moths are common soil pests and damage lettuce, strawberries and chrysanthemums. They fly at dusk on the day of emergence, the females seeking the males. The sex ratio is approximately 50/50. After mating females lay between 200 and 1,600 eggs, with a mean of about 600 over a period of 4 days. Mercury-vapour light-trap catches showed the flight period to be mainly in June. The eggs, which are described, were about 80% fertile and hatch more rapidly at 20° C, after 11 and 24 days. At 5° C they did not hatch.

Larvae of the Ghost Swift moth, *Hepialus humuli* L., were cultured in small plaster of Paris cells or in vials containing plaster of Paris, and fed on pieces of carrot. The widths of the larval head capsules allowed 12 instars to be distinguished; at high temperatures there may be more than 12 instars. The general growth curve of the larva was S-shaped, but larvae lost weight for several days in each instar before moulting. The daily intake of food was weighed and the conversion ratio was small, ranging from 0·0058 to 0·04, as compared with 0·205 to 0·49 with other caterpillars. The larvae did not develop at 5° C, there was little development at 10° C, the optimum for survival was 15° C, although development was faster at 20° C. Larvae in outdoor cultures developed faster than those kept at 10° C and slower than those at 15° C, and had reached only the eighth instar by February of their first year. This, and other evidence, indicates that the usual life cycle lasts 2 years. A single larva required about 60 g, or one-sixth of a pound of carrot to complete its development, so a large population of 50,000 larvae per acre could eat 18% of a carrot crop yielding 20 tons/acre or seriously damage lettuce crops with 40,000 plants/acre.

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10.14 EDWARDS, C. A. & (DENNIS, E. B.) (1964) Phytotoxicity of insecticides and acaricides. Part III. Soil applications. *Plant Path.* **13**. (In the press.)

In two trials aldrin at 3, 15 and 60 lb a.i./acre and DDT at 3, 20 and 100 lb a.i./acre were rotovated into an infertile heavy soil containing little organic matter. Dwarf beans, cabbage, carrots, cucumbers, lettuces, onions, peas, potatoes, strawberries, swedes and tomatoes were grown, some as transplanted seedlings and the others direct from seed. Results were variable, and experiments were repeated in pots under glass with crops grown in compost treated with similar dosages of insecticides. Beans were susceptible, swedes and cabbage slightly so, but the growth of cucumbers, carrots and parsnips was stimulated. Plant growth and yield of tomatoes was decreased at all doses of DDT. Other effects included both stunting and increased growth.

10.15 GERARD, B. M. (1963) An earthworm labelled with radioactive tantalum. *Nature, Lond.*, **200**, 486–487.

An adult *Lumbricus terrestris* L. apparently suffered no ill-effects when 2·0 mg radioactive tantalum wire (tantalum-182), with a half-life of 115 days and a radioactive value of about 12 μc, was introduced into its coelom. Three months later on 21 October it was recaptured from its burrow apparently unharmed, although the tantalum had moved in the coelomic cavity to a segment 1 in. from the anus. The worm could be detected when it was 8 in. below the surface of the soil.

10.16 HEATH, G. W., EDWARDS, C. A. & ARNOLD, M. K. (1964) Some methods for assessing the activity of soil animals in the breakdown of leaves. *Pedobiologia* **2** (4). (In the press.)

By enclosing leaf discs in nylon bags with different-sized meshes, the importance of different groups of soil animals, or of micro-organisms alone, in breaking down leaves can be assessed. Visual and photometric methods of measuring the rate at which leaf discs are eaten and disappear gave results agreeing closely with those obtained by weighing. Leaf discs 2·5 cm diameter from the same part of a single tree were used for this comparison.

10.17 LEWIS, T. (1963) The effect of weather on emergence and take-off of overwintering *Limothrips cerealium* Haliday (Thysanoptera). *Ann. appl. Biol.* **51**, 489–502.

The temperature threshold for take-off of *Limothrips cerealium* is 18·4° C, but a temperature-dependent development period is necessary before thrips are ready to fly in spring. In April and May 1960 this ranged from 4 days at 35° C to 42 days at 10° C. Thrips hibernating on the warm southern side of trees were therefore ready to fly sooner than those on the cooler northern side.

Overwintering thrips were observed emerging from pine bark, and their take-off was recorded by a suction trap. Most thrips emerged when the sun shone on the bark, and they usually took-off a few minutes later, after combing and flexing their wings.

Temperature was the most important single factor influencing take-off: apparent temperature thresholds for take-off ranged from 14° C, using air temperature, to 19° C, using bark temperature. These arbitrary values, which reflected the body temperature threshold, indicated the importance of standard procedures for measuring temperatures, and were a guide to expected behaviour in the field. Take-off was not retarded by temperatures up to 35° C.

Low light intensity decreased numbers which took off 1–2 hours before sunset,

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but in spring the temperature often fell below the take-off threshold before this. Relative humidity and wind speed were less important, and take-off occurred at humidities from 27 to 53% and wind speeds from 2·5 to 4·5 m.p.h. Sultry weather was not a necessity for spring flight.

10.18 LEWIS, T. (1964) The weather and mass flights of Thysanoptera. *Ann. appl. Biol.* **53**, 165–170.

Mass flights of Thysanoptera occur when temperatures rise above the flight threshold after migrants have accumulated on plants at temperatures high enough for metamorphosis but too low for flight. Most species fly in sunny, settled weather with slight convection and a maximum temperature of at least 20° C.

10.19 MADGE, D. S. (1962) The biology of the cutworm *Tryphaena pronuba* L. (Lepidoptera: Noctuidae). *Ent. exp. & appl.* **5**, 261–269.

Adults of the cutworm *Tryphaena pronuba* L. fly between June and October and lay about 1,400 eggs. There are seven larval instars, followed by a prepupal (diapause) stage in January and pupation in May. The effects of different temperatures on the rate of egg, larval and pupal development are described and discussed.

10.20 MADGE, D. S. (1964) The light reactions and feeding behaviour of larvae of the cutworm *Tryphaena pronuba* L. Part I. Laboratory investigations. *Ent. exp. & appl.* **7**. (In the press.)

Each larval instar of the cutworm *Tryphaena pronuba* L. has a characteristic photic reaction in monochromatic light. Instar I larvae are photopositive and instar VII larvae photonegative in 0·5 lux to 5,000 lux. Instar II larvae are photopositive, but photosensitivity decreases in bright light. Instars III and V larvae are attracted to dim light and repelled by brighter light and become photonegative. Low temperature reverses the photopositive reaction of instar I larvae, the last instar remaining photonegative. Starvation and light-adaptation modifies, but does not generally change their overall photic reactions. Cutworm larvae remain unaffected by different overhead light gradients. Instar I larvae are indifferent to black objects, instar V larvae are attracted towards them. Photonegative cutworm larvae are mostly sensitive to yellow light, but they are unable to distinguish this colour from darkness.

10.21 MADGE, D. S. (1964) The light reactions and feeding behaviour of larvae of the cutworm *Tryphaena pronuba* L. Part II. Field investigations. *Ent. exp. & appl.* **7**. (In the press.)

Field observations are correlated with laboratory experiments (Part I). Instar I larvae are diurnal, instars III to VII larvae nocturnal and instar II larvae intermediate. The entry of instar I larvae into the soil is partly determined by decrease in temperature. The activity of instars III to VII larvae is generally unaffected by temperature but is mainly related to absence of light. Instar I larvae are indifferent to moonlight; instar VII larvae are repelled by it.

10.22 MURPHY, P. W. (1962) A radioisotope method for determination of rate of disappearance of leaf litter in woodland. In: *Progress in Soil Zoology* I, ed. P. W. Murphy. London: Butterworths, 357–363.

Details are given of an isotope-labelling technique, which enables leaves of known age to be recovered from the forest floor. They are marked while on the tree, with a spot of artists' oil colour to which has been added tantalum 182, and are found on the ground with a portable Geiger–Müller detector.

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Preliminary measurements on the rate beech-leaf litter disappears are given, and the effect of gamma radiation on insects and other invertebrate animals is discussed.

Bee Department

Book

11.1 BAILEY, L. (1963) *Infectious diseases of the honey bee*. London: Land Books (Hutchinson), 176 pp.

Thesis

11.2 SPRADBERY, J. P. (1963) A study of the biology of British Vespine wasps (Hymenoptera: Vespidae) with reference to the problems of caste differentiation. Ph.D. Thesis, University of London.

General Papers

11.3 BAILEY, L. (1963) *The "Isle of Wight disease": the origin and significance of the myth*. Ilford: Central Association of Beekeepers, 9 pp.

11.4 BUTLER, C. G. (1963) The honey-bee colony—life history. In: *The hive and the honey bee*, ed. R. A. Grout. Illinois: Dadant and Sons, Inc., pp. 35–69.

11.5 BUTLER, C. G. (1963) Pheromones in sexual processes in insects. *Symposium* No. 2. *Insect Reproduction*, R. ent. Soc. Lond. pp. 66–67.

11.6 FREE, J. B. (1963) The foraging behaviour of honeybees in fruit orchards. *Anim. Behav.* **11**, 604–605.

11.7 SIMPSON, J. (1962) The salivary glands of *Apis mellifera* and their significance in caste determination. 4th Congr. Internat. Union for the Study of Social Insects. Pavia, 1961. *Symp. Genet.* **10**, 173–188.

11.8 SIMPSON, J. (1963) Work at Rothamsted on honeybee swarming. *Rep. Rothamst. exp. Sta.* for 1962, 254–259.

Research Papers

11.9 BAILEY, L. (1963) The habitat of *Bacterium eurydice*. *J. gen. Microbiol.* **31**, 147–150.

The alimentary canal of adult bees is the main source of *Bacterium eurydice* which spreads between bees and to larvae, pollen and honey, from the mouths of infected adults. Most natural spread happens when foraging activity is greatest, probably because infected adults then collect and contaminate pollen, which is soon eaten by the young brood-rearing bees.

11.10 BAILEY, L. (1963) The pathogenicity for honey-bee larvae of micro-organisms associated with European foulbrood. *J. Insect Pathol.* **5**, 198–205.

Tests made on larvae in normal bee colonies with pure cultures of *Streptococcus pluton* (White), *Streptococcus faecalis* (Andrews and Horder) and *Bacillus alvei* (Cheshire and Cheyne), three bacterial species commonly associated with European foulbrood (E.F.B.), showed that *S. pluton* was the primary pathogen.

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The results, together with other recent work, show that *S. pluton*, was the cause of disease diagnosed as E.F.B. in many parts of the world. Of the other associated bacterial species, *Bacterium eurydice* (White), which is the most common, and *S. faecalis*, probably have supplementary pathological effects. *Bacillus alvei* and other less common bacilli are saprophytes of the dead larvae.

11.11 Bailey, L., Gibbs, A. J. & Woods, R. D. (1963) Two viruses from adult honey bees, (*Apis mellifera* Linnaeus). *Virology* **21**, 390–395.

Two viruses were isolated from honeybees. When fed to, sprayed on or injected into healthy bees either virus made the bees become trembly within a few days, but whereas bees infected with one virus died quickly (acute "paralysis"), bees infected with the other survived for several days after first showing symptoms (chronic "paralysis"). Purified preparations of acute bee paralysis virus (ABPV) contained isometric particles about 28 mμ in diameter, whereas those of chronic bee paralysis virus (CBPV) contained particles of irregular shape about 27 mμ × 45 mμ. Both viruses occurred in apparently healthy bees, but only CBPV particles were numerous in diseased bees from colonies naturally affected with the disease called "bee paralysis". On inoculation to healthy bees the symptoms caused by CBPV resembled those of the naturally occurring disease more than did those caused by ABPV.

11.12 Butler, C. G. & Fairey, E. N. (1963) The role of the queen in preventing oogenesis in worker honeybees. *J. apic. Res.* **2**, 14–18.

Ovary development in worker honeybees is inhibited by 9-oxodecenoic acid or its vapour. A scent from the queen, in addition to her 9-oxodecenoic acid, also inhibits oogenesis in workers, but is less effective than the acid. The scent and acid do not work together synergically. Neither 9-oxodecenoic acid nor queen scent, nor the two together, are as effective in inhibiting oogenesis in workers as access to a live queen. Older, mated queens are more effective than younger, virgin ones. Injection of 9-oxodecenoic acid partially inhibits ovary development in workers, but does not inhibit queen rearing by them. The mode of action of this acid is still uncertain.

11.13 Free, J. B. (1962) The attractiveness of geraniol to foraging honeybees. *J. apic. Res.* **1**, 52–54.

Experiments showed that geraniol (suggested as the principal volatile component of honeybee scent-gland secretion) is attractive to foragers, but that it is not nearly as attractive as scent-gland odour itself. Foragers could distinguish geraniol from scent-gland odour, and it is concluded that the attractiveness of the latter must depend partly on other components than geraniol.

11.14 Free, J. B. (1963) The flower constancy of honeybees. *J. Anim. Ecol.* **32**, 119–131.

The flower constancy of honeybees on successive days was studied by removing and identifying pollen collected by marked pollen-gatherers. Removing pollen from the bees lessened their tendency to collect it later; chilling the bees before marking did not influence their foraging behaviour; neither treatment affected their constancy to the kind of pollen collected. There was no sequence of nectar or pollen collection with increasing age of bee.

Most bees collected only a few of the pollens available to them; bees collecting the most common pollens tended to be the most constant. In general, the proportion of bees collecting their original kind of pollen decreased as the number of their foraging days increased, and only about half were still doing so after 1 week; the rate of decrease differed in different experiments. No bee

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regularly collected different pollens at different times of the day. When the pollen they were accustomed to collect was unavailable for a day most foraged for nectar only or stayed at home. Most bees that changed to another pollen probably did so when the pollen they had previously collected became scarce or unattractive for long periods. About 6% of loads contained more than one species of pollen. Bees that collected mixed loads were more inclined to do so later.

When a colony was moved to a new site with a similar flora as the old one, the bees tended to visit the same species as before, but when one species predominated, bees that had not visited it before tended to do so.

11.15 FREE, J. B. & SPENCER-BOOTH, Y. (1962) The upper lethal temperatures of honeybees. *Ent. exp. and appl.* **5**, 249–254.

Survival of bees at high temperatures depended on the duration of exposure and relative humidity. At the higher temperatures bees survived short periods only and survived longer as relative humidity decreased, because they could cool themselves more by evaporation. At somewhat lower temperatures bees survived longer at higher relative humidities because desiccation was the limiting factor.

11.16 FREE, J. B. & SPENCER-BOOTH, Y. (1963) The foraging areas of honeybee colonies in fruit orchards. *J. hort. Sci.* **38**, 129–137.

From studies with groups of different numbers of hives in orchards of different shapes and sizes it is concluded that colonies for pollination should be placed in small groups, each near the centre of the area its bees are to pollinate.

11.17 FREE, J. B. & SPENCER-BOOTH, Y. (1963) The pollination of mustard by honeybees. *J. apic. Res.* **2**, 69–70.

The presence of honeybees in bee-proof cages put over plots of mustard substantially increased the seed yield of *Brassica alba*, but not of *B. juncea*.

11.18 FREE, J. B. & SPENCER-BOOTH, Y. (1963) The effect of examining honeybee colonies on their subsequent foraging activity. *J. apic. Res.* **2**, 67–68.

Routine manipulation of colonies inevitably hinders the activities of housebees in several ways, but does not seem to interfere with foragers.

11.19 SIMPSON, J. (1963) Queen perception by honeybee swarms. *Nature, Lond.* **199**, 94–95.

A honeybee swarm does not form a stable cluster unless it has a queen. A colony deprived of its hive, combs and queen could be stabilised by a queen caged so that the worker bees could not touch her, a cage that had held a queen or a cage containing the crushed head (other parts were ineffective) of a queen. A swarm in flight can perceive whether or not it has a queen.

11.20 SIMPSON, J. & RIEDEL, I. B. M. (1963) The factor that causes swarming by honeybee colonies in small hives. *J. apic. Res*, **2**, 50–54.

Restricting the hive space available to adult bees produced swarming, but restricting the space for brood did not. Neither treatment appeared to cause queen rearing, and several colonies swarmed without occupied queen cells, showing that queen rearing is not an essential preliminary to the swarming caused by insufficiency of hive space.

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Statistics Department

Book

12.1 (Fisher, R. A.) & Yates, F. (1963) *Statistical tables for biological, agricultural and medical research*. 6th Edition. Edinburgh: Oliver & Boyd, 148 pp.

General Papers

12.2 Healy, M. J. R. (1963) Bibliography of the works of Sir Ronald Fisher. *J. R. statist. Soc. A* **126**, 170–178.

12.3 Leech, F. B. (1963) Electronic computers in relation to veterinary science. *Proc. R. Soc. Med.* **56**, 563–564.

12.4 Yates, F. & (Mather, K.) (1963) Ronald Aylmer Fisher: 1890–1962. *Biogr. Mem. Fellows roy. Soc.* **9**, 91–129.

Research Papers

12.5 (Blood, J. W. *et al.*), Boyd, D. A., Church, B. M. & Hills, M. G. (1963) *Survey of Fertiliser Practice, 1962*. Preliminary Report and Report part II. London: Ministry of Agriculture, Fisheries & Food, pp. 37 and pp. 43.

These two reports give detailed information on fertiliser practice in 1962 for 30 districts of England and Wales. The field work was done jointly by Advisory Soil Chemists of the National Agricultural Advisory Service and by representatives of the Fertiliser Manufacturers' Association.

Since the previous large-scale survey, consumption of fertilisers in England and Wales had increased by about 75% for N, 35% for P and 20% for K. For P and K the increases arose largely from an increase in the treated acreage, whereas for N one-third of the greater use on arable crops and one-half of that on permanent grass came from increased rates of application. The increases in average N dressings on tillage crops were much as one might have expected from the increased concentration of nutrients in fertilisers, had the rates of application of the fertilisers remained unchanged.

12.6 Boyd, D. A. (1963) The relationship between crop response and the determination of soil phosphorus by chemical methods. II. *Proc. Conf. on Soil Phosphorus*. Ministry of Agriculture, Fisheries and Food. (In the press.)

Results are given of a series of investigations by the National Agricultural Advisory Service Soil Chemists' Conference to compare the ability of different methods of soil analysis to predict crop responses to fertiliser.

For most soils, Olsen's (0·5*M*-$NaHCO_3$) was the most effective method; it was distinctly better than Morgan's reagent (including a modification of Morgan's using ammonium acetate in place of sodium acetate), and 1% citric acid. Two methods, 0·3*N*-HCl and 0·5*N*-acetic acid, did particularly badly. None of the methods was successful on Fen peat soils.

12.7 Boyd, D. A. & (Dermott, W.) (1964) Fertiliser experiments on maincrop potatoes, 1955–61. *J. agric. Sci.* (In the press.)

Results are given of 124 factorial experiments testing N, P and K fertilisers for maincrop potatoes; the experiments were done by National Agricultural

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Advisory Service Soil Chemists in the years 1955–61. An important feature of the work was the restriction of the experimental sites to particular soil series or complexes.

There were substantial differences between soil series in mean yield and in response to the lower levels of P and K; the influence of soil was less at larger rates of application. Alternative methods of soil classification which appeared to be associated with response were texture, experiments on the lighter-textured soils showing higher responses to K and depth of freely drained soil, soils with impeded drainage being associated with larger P responses. Responses to P and K were particularly large on soils in Wales and N.W. Cumberland.

For N, differences in response between soils were less important than differences from season to season; crops on the lighter-textured soils were rather more responsive to N. N response also varied with previous cropping, being greater after a cereal crop; after roots or leys on the heavier soils yields decreased sharply at high levels of N.

For most of the heavier-textured soils, and for sands and sandy loams deficient in P, the average optimal dressing was probably 1·0–1·5 cwt P_2O_5/acre (above the highest rate tested), and possibly more than 1·5 cwt for soils from Wales and Cumberland; for sands and sandy loams with medium levels of soil P the average optimum was 0·5–1·0 cwt P_2O_5/acre, but it was not more than 0·5 cwt P_2O_5/acre on soils high in P. The heavier soils generally showed only small responses to K, whereas soils from Wales and Cumberland and most sands and sandy loams had optima of the order of 2·0 cwt K_2O/acre. For N, the average optimum was only about 0·8 cwt N/acre, rather less than previous estimates, possibly because of seasons particularly unfavourable to N responses.

12.8 CHURCH, B. M. (1963) Information on lime requirements and the use of lime in England and Wales. *N.A.A.S. Quart. Rev.* No. 62, 55–62.

Estimates of lime requirements derived from the results of routine soil sampling are given for different regions of England and Wales. Information from fertiliser practice surveys on the use of lime, and on lime requirements on random samples of fields within selected districts is summarised.

12.9 (ELLISON, W.), BOYD, D. A. & CHURCH, B. M. (1963) Costs and returns for reseeded hills in Montgomeryshire. *J. R. agric. Soc.* (In the press.)

During the 1939–45 war a considerable acreage of hill land in Montgomeryshire was reclaimed. The paper gives information from periodic surveys on the stock carried and on maintenance costs over a period of almost twenty years.

12.10 HEALY, M. J. R. (1963) Fitting a quadratic. *Biometrics* **19**, 362–363.

The relation $y = \beta_0 + \beta_1 t + \beta_2 t^2$ is most conveniently fitted by least squares if it is written in the form

$$y = \gamma_0 + \gamma_1 (t - \bar{t}) + \gamma_2 (z - \bar{z}) \text{ where } z = (t - \bar{t})^2$$

12.11 HEALY, M. J. R. (1964) A property of the multinomial distribution and the determination of appropriate scores. *Biometrika.* (In the press.)

Let $p_0, p_1, \ldots p_k$ be the parameters of a multinomial distribution and $\mathbf{p}^T$ the vector $(p_1, p_2, \ldots p_k)$. The dispersion matrix of the numbers falling into

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classes 1, 2, . . . k in a sample of N is $\mathbf{D} = N(\mathbf{p}^{\delta} - \mathbf{p}\mathbf{p}^{T})$. Then the inverse of $\mathbf{D}$ can be written down immediately in the form

$$\mathbf{D}^{-1} = N^{-1}(\mathbf{p}^{-\delta} + \mathbf{J}/S_k)$$

where $S_i = 1 - (p_1 + p_2 + \ldots + p_i)$ and $\mathbf{J}$ is a matrix whose elements are all units. If $\mathbf{D}$ is written in form $N\,\mathbf{U}^{T}\mathbf{U}$ where $\mathbf{U}$ is upper triangular, the elements of $\mathbf{U}^{-1}$ are given by

$$U^{jj} = + \left(\frac{1}{p_j} + \frac{1}{S_j}\right)^{\frac{1}{2}}$$

$$U^{ij} = + \left(\frac{1}{S_j} - \frac{1}{S_{j-1}}\right)^{\frac{1}{2}}, \; i < j$$

$$= 0 \qquad\qquad i > j$$

The same matrices arise in the problem of assigning optimum scores to items assigned to one or other of $k + 1$ different categories.

12.12 LEECH, F. B., VESSEY, M. P., (MACRAE, W. D., LAWSON, J. R. *et al.*) (1964) *Brucellosis in the British dairy herd.* London: H.M. Stationery Office. (In the press.)

During 1960–61 a national survey of the incidence of brucellosis was made on a random sample of dairy herds. It was estimated that about 25,000–30,000 herds and 65,000–70,000 cows were infected with the disease.

About 6% of cows in the survey calved up to the 270th day of gestation. Brucella was associated with about 7% of these premature calvings.

Strain 19 vaccine when given to immature animals appeared to halve the frequency of infection. There was no evidence of any useful result following the vaccination of adult cows.

In the national dairy herd the major economic losses per annum associated with brucellosis were estimated to be 11,000 calves, 3½ million gal of milk and the cost of vaccination with Strain 19.

Some information was obtained from the survey which although unrelated to the study of brucellosis was included for its general interest.

12.13 LEECH, F. B., VESSEY, M. P. & (MACRAE, W. D.). (1964) *Disease, wastage and husbandry in the British dairy herd. Report of a second National Survey in 1958–59.* London: H.M. Stationery Office. (In the press.)

The second National Survey of Disease, Wastage and Husbandry covered the period from 1 October 1958 to 30 September 1959, and used a different sample of dairy herds from the survey in 1957–58.

The results agree closely with those published for the first survey, and the present report is largely concerned with the main points of difference. Some studies of the combined data for both surveys are also described, mainly concerning mastitis, acetonaemia and Johne's disease. More detailed estimates of economic loss are given than was possible for the 1957–58 survey.

12.14 LEECH, F. B., VESSEY, M. P. & (MENZIES, D. W.) (1964) *A survey of the losses of breeding ewes in England and Wales in 1958–59.* London: H.M. Stationery Office. (In the press.)

A simple survey covering the period from October 1958 to September 1959 showed that 7·6% of breeding ewes in England and Wales died during the year, three-quarters of the deaths occurring during the months October to March.

Losses in the first 6 months were greatest in western areas and at altitudes below 950 ft.

The survey also provided estimates of the breed popularity of ewes and tups in England and Wales.

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12.15 PATTERSON, H. D. (1964) Theory of cyclic rotation experiments. *J. R. statist. Soc. B*, **25**. (In the press.)

The paper reviews some of the statistical problems arising in the design and analysis of long-term cyclic experiments comparing different crop rotations. Three types of design are distinguished and their properties considered. These are basic designs with all phases of the rotations in each block, reduced designs with mutually exclusive groups of phases kept in separate blocks and phase-confounded designs in which some contrasts between test crops are partially confounded with block differences.

Methods of analysing the yields of test crops by estimating the mean effects of the rotations over the years and regressions on seasonal and time variates are discussed theoretically for replicated experiments of basic or reduced design. The analysis is complicated by correlations between yield values recurring on the same plots and by lack of homogeneity in residual year-to-year variations in rotation effects. The main topics considered are: (1) the estimation of errors; (2) the losses of information due to using unweighted means and regressions ignoring the correlations; (3) methods for recovering this information.

12.16 SIMPSON, H. R. (1964) Appendix to: *The home and the school* by J. W. B. Douglas. London: MacGibbon & Kee.

A brief description of the method of fitting constants to non-orthogonal data and its application to intelligence test scores of children of the National Survey of Health and Development.

12.17 VERNON, A. J. & (ALLISON, J. C. S.) (1963) A method of calculating net assimilation rate. *Nature, Lond.* **200**, 814.

The use of smoothed values of the dry weights of leaf areas on successive occasions for the calculation of net assimilation rate gives much less variable results than those calculated directly from increases in dry weight and leaf areas. This leads to much greater precision in the interpretation of experiments on net assimilation rate.

12.18 (WATSON, W. A.) & VESSEY, M. P. (1963) A three-year laboratory study of pathological material received from Yorkshire sheep flocks with an abortion problem. *Vet. Rec.* **75**, 625–629.

The incidence of vibriosis and virus abortion was studied in aborted and stillborn lambs and placentae sent to the Veterinary Investigation Centre, Leeds, during the three years 1959–61. Laboratory diagnostic techniques are compared and the incidence of vibriosis in multiple sets of foetuses discussed. Various factors, including year of study, foetal mummification, state of preservation and age of specimen, are shown to be related to the diagnosis of infection. Reference is also made to the results of testing a series of ewes by the complement fixation test for antibody to the Psittacosis agent of virus abortion.

12.19 YATES, F. (1963) What is wrong with the teaching of statistics? *Sankhya*. (In the press.)

Formal teaching of statistics is increasing greatly, both in the universities and colleges of higher technology. The content of some of the present courses is examined. It is suggested that: (*a*) an excessively axiomatic mathematical approach is often adopted, and (*b*) that many syllabuses are out-of-date and include methods which are discredited or of little practical utility.

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12.20 YATES, F. (1964) Sir Ronald Fisher and the design of experiments. *Biometrics*. (In the press.)

The history of the development of the Fisherian methods for the design and analysis of replicated experiments is given. Difficulties experienced by mathematical statisticians in the acceptance of the new methods and the criticisms advanced are also discussed.

Field Experiments Section

RESEARCH PAPERS

13.1 DYKE, G. V. (1964) Why leys? *Exp. Husbandry* **10**, 101–111.

The yields of dry matter of the grazed, cut and lucerne leys, the seeds hay and permanent and reseeded grasses in the Rothamsted Ley–Arable experiments are summarised. The grazed leys yielded less dry matter than the cut leys or lucerne. Comparison with the old grass indicates that the leys sown in the second cycle yielded less than in the first cycle. The grazed leys on average yielded the same as the reseeded on Highfield (after old grass) less on Fosters (old arable land). The cut grass leys yielded less than the reseeded in the years when it was cut for hay or silage before aftermath grazing. On Highfield the reseeded grass yielded more than the old sward up to the 7th year after reseeding. Thereafter the mean yields were equal, but with much N the old grass outyielded the reseeded from the 10th to the 12th seasons. Fosters reseeded yielded less than Highfield reseeded up to the 8th season, but more thenceforward. Responses to extra N were larger for all grasses (except the seeds hay) on Highfield than on Fosters—in contrast to the arable test crops of the experiment.

13.2 DYKE, G. V. (1964) Restricted randomisation for blocks of 16 plots. *J. agric. Sci.* **62**. (In the press.)

A method is described of obtaining restricted randomisations for factorial experiments in blocks of 16 plots; this avoids patterns likely to give particularly inaccurate estimates of main effects or interactions. A full enumeration would not provide obviously better sets than the 83 distinct ones so obtained. A key to the sets and instructions for obtaining designs are given.

Broom's Barn Experimental Station

GENERAL PAPERS

16.1 (COLE, J. C., EASTOP, V. F.) & HEATHCOTE, G. D. (1963) Winged aphids trapped in an abaca plantation in British North Borneo. *Ent. mon. Mag.* **98**, 270–271.

16.2 DUNNING, R. A. (1963) Aphid control; timing important. *Farming World*—Sugar-beet supplement, March.

16.3 DUNNING, R. A. (1963) Mangold clamps and aphid numbers. *Brit. Sug. Beet Rev.* **31**, 133–134.

16.4 DUNNING, R. A. (1963) Reducing the insect damage. *Cambridgeshire Times*—Agricultural supplement, 22 March.

16.5 HULL, R. (1963) Control of yellows in sugar beet. *J. nat. Inst. agric. Bot.* **9**, 452–455.

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16.6 HULL, R. (1963) The influence of disease on yield of sugar beet. *Ann. appl. Biol.* **51**, 516–517.

16.7 HULL, R. (1963) Sugar beet yellows in Great Britain, 1962. *Plant Path.* **12**, 155–156.

16.8 HULL, R. (1963) Sugar beet yellows and the seed crop. *Brit. Sug. Beet Rev.* **31**, 125–128.

16.9 HULL, R. & DUNNING, R. A. (1963) Diseases and pests of sugar beet, fodder beet and mangolds. In: *Insecticide and fungicide handbook*. ed. H. Martin. Oxford: Blackwell Scientific Publications, Chapter 7, pp. 112–121.

16.10 TINKER, P. B. H. (1963) Manuring—with 1963 price system in view. *Farming World*—Sugar-beet supplement, March.

RESEARCH PAPERS

16.11 BYFORD, W. J. (1963) Field emergence and laboratory germination of sugar-beet seed. *Plant Path.* **12**, 174–177.

The number of seedlings that emerge in the field from untreated sugar-beet seed depends on both germination capacity of the seed-balls and the number contaminated with *Pleospora betae*. In field tests with 14 samples of seed differing in germination capacity and *P. betae* contamination, the increases in emergence after treatment with an ethyl mercury phosphate steep was attributed to control of *P. betae*. Germination capacity of beet-seed lots was not clearly related to seed-ball weight or the numbers of mature or of undeveloped seed in the seed-balls.

16.12 BYFORD, W. J. (1963) *Pleospora bjoerlingii* nom. nov. *Trans. Brit. mycol. Soc.* **46**, 614.

Pleospora betae Björling is shown to be a homonym, and the name *P. bjoerlingii* is proposed for this fungus, the perfect state of *Phoma betae* Frank.

16.13 BYFORD, W. J. & HULL, R. (1963) Control of sugar-beet downy mildew (*Peronospora farinosa*) by sprays. *Ann. appl. Biol.* **52**, 415–422.

No fungicide tested gave more than partial control of sugar-beet downy mildew in root crops or steckling beds, and even frequent spraying beginning shortly after seedling emergence rarely did more than halve the incidence. This degree of control is not adequate for commercial use on root crops, but is helpful on steckling beds in conjunction with other control measures.

16.14 COCKBAIN, A. J., GIBBS, A. J. & HEATHCOTE, G. D. (1963) Some factors affecting the transmission of sugar beet mosaic and pea mosaic viruses by *Aphis fabae* and *Myzus persicae*. *Ann. appl. Biol.* **51**, 133–143.

(For summary see No. 10.11.)

16.15 HEATHCOTE, G. D. (1963) The effect of coccinellids on aphids infesting insecticide-treated sugar beet. *Plant Path.* **12**, 80–83.

Predators rarely control aphids adequately, and it is therefore necessary to use insecticides to do so. The insecticides tested on sugar-beet crops affected aphid predators only temporarily. When insecticides were no longer used, aphid populations sometimes increased more than on unsprayed crops, but coccinellids recolonised the sprayed crops and populations of aphids and predators were soon

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similar on sprayed and unsprayed crops. The insecticides affected the coccinellid population on beet more by destroying its source of food then by directly killing the beetles.

16.16 HEATHCOTE, G. D. & (WARD, J.) (1963) The effect of DDT on *Myzus persicae* (Sulz.) and *Brevicoryne brassicae* (L.) (Aphididae) in relation to the spread of cauliflower mosaic and cabbage black ring spot viruses. *Bull. ent. Res.* **53**, 779–784.

(For summary see No. 7.21.)

16.17 (REES, A. R.) & TINKER, P. B. H. (1963) Dry matter production and nutrient content of plantation oil palms in Nigeria. I. Growth and dry matter production. *Plant & Soil* **19**, 19–32.

Seventeen palms selected as representative of six age-groups ranging from 7 to 22 years were cut down, split into their component parts and the dry weights obtained. Plant composition and dry-matter accumulation since planting are given together with estimates of annual production expressed as dry matter per hectare (crop-growth rate) and on the basis of leaf area (net assimilation rate). The results are discussed in relation to productivity of other plants in temperate regions and in the tropics, and reasons are suggested for the comparatively slow rate ($1{\cdot}95 \times 10^4$ kg/ha/annum) adult palms produce dry matter.

16.18 TINKER, P. B. H. (1963) Changes occurring in the sedimentary soils of southern Nigeria after oil palm plantation establishment. *J. W. Afr. Inst. Oil Palm Res.* **4** (13), 66–81.

The only important effect is a progressive soil loss of potassium; calcium and magnesium are also lost, but organic matter is hardly affected. The loss of exchangeable potassium from the top 10 ft of soil is about 300 lb/acre over 15 years, which is approximately half the palms' total requirement.

16.19 TINKER, P. B. H. & (SMILDE, K. W.) (1963) Cation relationships and magnesium deficiency in the oil palm. *J. W. Afr. Inst. Oil Palm Res.* **4** (13), 82–100.

Pot experiments with soil and sand showed that magnesium deficiency is easily induced by applying potassium, whereas calcium dressings have little or no effect. Similar results were obtained in field experiments. Severe magnesium-deficiency symptoms do not necessarily imply a great loss in yield.

Large applications of potassium and ammonium sulphates on young replanted palms caused magnesium deficiency symptoms to appear. Leaching losses of magnesium were measured, and a critical Mg/K ratio in the soil found for these conditions.

16.20 TINKER, P. B. H. & (SMILDE, K. W.) (1963) Dry matter production and nutrient content of plantation oil palms in Nigeria. II. Nutrient content. *Plant & Soil*, **19**, 350–363.

Figures are given for the amount of nutrients contained in palms of different ages with reference to fertiliser policy in replanted fields. A high proportion of the net uptake of phosphate and potassium is accumulated in fruit bunches, and, as a result, permanently lost to the soil. Under Nigerian conditions a deficiency of potassium readily appears, and fertiliser is required in replanted areas to supply at least part of the total demand.

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Soil Survey of England and Wales

Book

17.1 BALL, D. F. (1963) *The soils and land use of the district around Bangor and Beaumaris*. London: H.M. Stationery Office, ix, 182 pp.

General Papers

17.2 *Soil map on 3rd Edition Sheet 188 (Cambridge)* (1962) Southampton: Ordnance Survey.

17.3 AVERY, B. W. (1963) Soil Classification in Britain. *Pédologie* **13**. (In the press).

17.4 BURNHAM, C. P. (& DERMOTT, W.) (1963) Preliminary studies on the agricultural significance of soil series in the West Midlands. *Rep. Welsh Soils Discussion Group*. No. 5. (In the press.)

17.5 CRAMPTON, C. B. (1963) Gleying in soils within the region of the River Neath catchment. *Rep. Welsh Soils Discussion Group*. No. 4.

17.6 CRAMPTON, C. B. (1963) Potential horticultural soils in Glamorgan. *Growers Digest*. No. 77, 2–9.

17.7 MACKNEY, D. (1963) Soil as a factor in agricultural land classification. *Tech. Rep. agric. Land Service* No. 18, 3–14.

17.8 OSMOND, D. A. (1963) The work of the Soil Survey and its possible contribution to an agricultural land classification system for Britain. *Tech. Rep. agric. Land Service* No. 18, 103–106.

Research Papers

17.9 CLAYDEN, B. (1963) The relationship of soil development to site on Culm shales. *Proc. Ussher Soc.* **1**, 54–55.

17.10 CRAMPTON, C. B. (1963) The development and morphology of iron pan podzols in Mid and South Wales. *J. Soil Sci.* **14**, 282–302.

A topographic sequence of iron pan podzols on loamy and silty parent materials in a zone of high relief and high rainfall was investigated. In the eluvial horizon of a soil designated podzol with gleying the cores of the peds are anaerobic and it is suggested that iron is mobilised here, by microbial action, to be deposited in a thin, discontinuous iron pan near the aerated edge of the peds. The illuvial horizon is well aerated both in this soil and in a peaty gley podzol having an undulating iron pan at the base of the eluvial horizon. Pollen analyses suggest the earliest vegetation was high forest mainly of oak (when podzolisation probably commenced) which was replaced by more open forest with ferns. Gleying probably occurred under the succeeding ericaceous flora and grassland is now extensive.

17.11 CRAMPTON, C. B. (1963) Contrasting vegetational histories of certain soils in South Wales. An interpretation of their pollen content. *J. Ecol.* **51**, 453–459.

Non-tree pollens (e.g. Gramineae and Ericaceae) and Pteridophyte spores (chiefly Polypodium) assume major importance in soils in the high land. Former open woodland with ferns gave way to a flora, at first, mainly of Ericaceae and later of grasses. Approaching the Vale of Glamorgan and an area mainly of

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calcareous soils, tree pollen becomes of more importance and Gramineae and Pteridophytes of much less importance. Oak dominated thick forest in the Vale during the time represented by the pollen distribution in soil profiles.

17.12 CRAMPTON, C. B. & (WEBLEY, D. P.) (1963) The correlation of prehistoric settlement and soils in Gower and the South Wales Coalfield. *Bull. Bd Celtic Studies* **19**. (In the press.)

The location of Roman sites appears not to be related to soil characteristics, and Iron Age forts are commonly sited on dominating hilltops which, in Gower, are often close to the sea. Neolithic sites and Bronze Age barrows are preferentially sited on free draining soils but near poorly drained soils. The climatic, vegetational and edaphic environment has greatly changed since the Bronze Age, and although these tombs were probably erected on *sols bruns acides* under oak forests, the soils are now in the podzol area. On lower slopes there would have been less acid soils better suited for an arable or pastoral husbandry.

17.13 HODGSON, J. M. (1963) Tangmere and Waterbeach. *Sussex Notes and Queries* **16**, 12–15.

The distribution and origin of alluvial deposits near Tangmere are described and offered as evidence for the derivation of the place-names of Tangmere and Waterbeach.

17.14 THOMASSON, A. J. & AVERY, B. W. (1963) The soils of Hertfordshire. *Trans. Herts. nat. Hist. Soc.* **25**, 247–263.

A coloured soil map, at the scale of 4 miles to 1 in., showing 12 soil associations, is described with details of the soil profile characteristics and descriptions of the soil series.

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