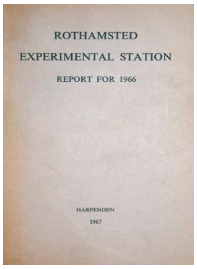
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Physics Department

Thesis

1.1 Wangati, F. J. (1966) A study of soil and plant factors in evaporation. M.Sc. Thesis, University of London.

General Papers

1.2 Monteith, J. L. (1967) Patterns and progress of research. *Proc. UNESCO Symposium*, Copenhagen, (1965). (In the press.)

1.3 Penman, H. L. (1967) Water use in agriculture. British Association Symposium on "Conservation and use of Water Resources", Nottingham, 1966. *J. Inst. Water Engrs.* (In the press.)

Research Papers

1.4 Bull, T. A. (1967) Leaf expansion in field bean (*Vicia faba* L.) as related to daily maximum temperatures. *J. appl. Ecol.* (In the press.)

Leaf expansion in beans was measured daily in the field from May to August 1966. In the early stages of growth, until the leaf area index (L) reached about 3, relative leaf growth rate was closely related to daily maximum air temperature. Previous results from several other temperate crops show this relation to be general until L reached about half its final value. Combining the present and previous results, relative leaf growth rate (R_L) and daily maximum temperature ($T°$ C) are related by $\log_{10} R_L = 0{\cdot}003T + \bar{2}{\cdot}316$, giving $Q_{10} = 2{\cdot}1$ for leaf expansion.

When the above expression and actual daily maximum temperatures were used to compare the effects of a warm or cool spring on leaf development the time taken to reach $L = 2$ differed by about 4 days. Similarly, the effect of higher temperature associated with later plantings in the same year was shown to shorten the time taken to achieve $L = 2$ by up to 23 days.

1.5 Cashen, G. H. (1967) Weissenberg effects and viscoelasticity. *Rheol. Acta.* **6**, 1–2.

Weissenberg effects refer to apparently anomalous flow phenomena when systems containing fluid are sheared. In the negative effect a dilatant paste is repelled from a rotating rod; the positive effect is shown by some (viscoelastic) polymer solutions that climb a rotating rod against the force of gravity and centrifugal force, in direct contrast to the behaviour of ordinary liquids. An explanation for these effects, inferred from the behaviour of water in clay pastes, is given. For the dilatant paste, the shear gives rise to larger pores near the rod; as atmospheric pressure is uniform over the surface, the gradient of the matric potential of the fluid provides a force pulling the paste radially outwards. For polymer molecules, in a solvent with small molecules, it is suggested that "spin drying" redistributes the solvent; in this case the gradient of the matric potential forces the solution towards the rod.

1.6 Cashen, G. H. (1967) Thixotropy and dilatancy. *Clay Min.* (In the press.)

The matric potential of water in gels of five-sixths neutralised aluminium montmorillonite (bentonite) and aluminium kaolinite changes during periods of shear and periods of rest. Shear increases the potential of water in bentonite gels, and in kaolinite gels containing little water, but decreases the potential in kaolinite gels containing more water. All these effects can be explained by

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changes in the curvature of water films at the gel–air interface. The difference between thixotropic and dilatant behaviour is the increasing and decreasing of the water potential on shearing. In dilatant pastes of silt-size particles, and for which the effects of electric charges are small, the pressure deficiency can reach large values after an increase in pore space, and this suffices to explain the characteristic features of dilatant behaviour.

1.7 CURRIE, J. A. (1967) Micro-structural parameters and plant growth. *Proc. Brno Symposium on Soil Management* (1966). (In the press.)

In any soil, nutrients and water are located within the structural units rather than between them. Successful exploitation of these resources should be considered in relation to the structural properties within these units, that is, the microstructural parameters. These determine the ability of the roots to get to nutrients and water, and of nutrients, air and water to get to the roots.

1.8 LONG, I. F. & FRENCH, B. K. (1967) Measurement of soil moisture in the field by neutron moderation. *J. Soil Sci.* **18**, 1–18.

Design, calibration, working precautions and field use of a soil-moisture meter are described. The probe carries a source ^{241}Am-Be and a detector $^{10}BF_3$ in an aluminium case, 3·4 cm diam and 17 cm long. Source and detector are as close to each other as possible, so giving a desired linear relationship between thermal neutron count and the volumetric water content around the probe. The portable scaler incorporates some new features of circuit design that lead to ease of operation and small size: it weighs 5 kg. Factors involved in calibration or the interpretation of a calibration curve are: resolving time of the scaler, the volume of soil explored by the neutrons, the effect of a moisture gradient and the possible effect of elements other than hydrogen.

Field trials were in two groups. In 1962 and 1963 frequent measurements were made in bare clay soil and under a nearby barley crop: from the profiles, the extraction of water from the bare soil was limited to the top 30 cm, but the barley roots took water out at least as deeply as the maximum depth of measurement then possible, 90 cm. In 1964 similar measurements under first-year Timothy and Meadow Fescue, irrigated and non-irrigated, showed that the total water abstracted by each was nearly the same, but the Timothy took most of its water from the top 40 cm of the profile, whereas the Fescue took more water from the lower depths. Combining the estimated deficits with known rainfall gives values of periodic evaporation in good agreement with aerodynamic estimates based on temperature, humidity and wind profiles above the crop, and in fair agreement with potential evaporation-rates calculated from routine weather records.

1.9 (MILTHORPE, F. L.) & PENMAN, H. L. (1967) Experimental studies of the factors controlling transpiration. IV. The diffusive conductivity of the stomata on wheat leaves. *J. exp. Bot.* **18**. (In the press.)

A leaf chamber (described in detail) was used alternately with a resistance porometer to measure resistance to viscous flow of air through the leaf, and with a diffusion porometer to measure the differential diffusive flow of hydrogen and air (V_H–V_A) through the leaf and the component of hydrogen flow ($V_{H'}$) moving straight across the leaf. The resistance of the mesophyll is needed for interpretation: estimates by three different methods for viscous flow did not agree very well, but two different methods for diffusive flow gave good agreement. For wheat leaves, only very large errors are important.

Formal analysis is in three appendices. I. Interpretation of viscous and diffusive flow in small pores involves some problems in molecular physics,

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complicated by the particular geometry of the wheat stoma. Making assumptions, some uncertainly, formal expressions are derived for the viscous resistance of a single stoma, r_v, and for the resistances to diffusion of hydrogen and air, of water vapour and of carbon dioxide, expressed as a "stomatal resistance" r_s per square centimetre of leaf surface. Maximum uncertainty is in the hydrogen/air analysis: that for water vapour and carbon dioxide is more reliable. II. An indication is given of the flow characteristics of the leaf-chamber system, from which r_v can be derived, and of the basis of the technique for estimating mesophyll resistance. III. The method of converting estimates of r_s into estimates of $V_H - V_A$ and $V_{H'}$ is given.

Experimental results are as nearly as possible in terms of measured quantities. For five leaves the dependence of $V_H - V_A$ on $V_{H'}$ agrees well with theoretical predictions; the dependence of $V_H - V_A$ (and $V_{H'}$) on r_v, on average, agrees well with prediction, but a small part of this involves an assumption that the stomata get shorter as they close. The general agreement is good enough to suggest that the formal expressions for r_s in terms of stomatal dimensions and molecular gas constants are reliable enough to be carried forward into future transpiration (and assimilation) studies. The minimum value of r_s for water vapour (c 3 sec cm^{-1}) is close to values found elsewhere by different techniques.

At very small stomatal openings there was a large deviation from predicted behaviour, such as would occur if the imposed excess air pressure further closed the stomata during viscous flow experiments.

1.10 MONTEITH, J. L. (1966) Physical limitations to crop growth. (Middleton Memorial Lecture, 1965) *Agric. Prog.* **41**. (In the press.)

Extrapolating from laboratory experiments on the relation between light energy and photosynthesis, the maximum photosynthetic efficiency expected outdoors is equivalent to the storage of about 8% of total solar radiation. Maximum efficiencies reported for sugar beet, sugar cane and maize are only 3 or 4% because of losses attributable to respiration and light saturation. Best yields over a whole season represent only 1–2% efficiency, because in early growth there are too few leaves to intercept available light, and in late growth photosynthesis gets slower. To compare actual and maximum possible rates of photosynthesis, three phases can be distinguished:

(i) A juvenile phase in which the ability to produce dry matter increases rapidly as the leaves expand at a rate determined mainly by the temperature of the environment. Root temperature may affect leaf expansion through the water balance of the plant.

(ii) A mature phase when there are enough leaves to intercept all the available light. Then the main physical factor determining photosynthesis is the receipt of radiation, but in real climates, year-to-year differences of radiation during the growing season are seldom big enough to produce detectable differences in yield. Nor is the concentration of carbon dioxide an important discriminant: it is usually slightly less than 300 ppm within the canopy of a crop, but is increasing everywhere with the burning of fossil fuels and may reach 400 ppm by the year 2000, with a consequent small increase of agricultural production.

(iii) A senescent phase during which production declines rapidly as leaves die and in which large rates of respiration from non-photosynthetic tissue can dominate the exchange of carbon dioxide. Then the net rate of dry-matter production will be negatively correlated with temperature in contrast to the juvenile phase when the correlation of growth and temperature is positive.

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Taking the growing season as a whole, the yield of dry matter seems to be determined mainly by the length of period in which the canopy is fully developed and by the maximum rate of photosynthesis by leaves exposed to bright light. Maize, sugar cane and tropical grasses have exceptionally fast maximum rates, and growth at 52 g m^{-1} (29 cwt $acre^{-1}$ day^{-1}) was recorded for a densely sown stand of *Zea mays* in California.

1.11 PENMAN, H. L. (1967) The role of vegetation in soil water problems. *Proc. UNESCO Symposium*, Wageningen (1966). (In the press.)

The main mechanism for producing unsaturation is evaporation from growing plants. In some clay soils the drying produces cracks whose persistence may determine soil permeability at saturation. Movement of water, and limiting values of soil-water contents, are determined by soil-moisture potentials, and energy supply is rarely a controlling factor. The lower limit of water content depends on the depth of root penetration, and the degree of ramification within the root depth: plant and soil characters determine these quantities. When the concept of "accessibility" is added to that of "availability" it is possible to explain some clashes in field evidence about how long actual evaporation remains equal to potential evaporation. Examples of plant/soil interactions considered include a range of soil depths, contrasts in plant type and different climates.

1.12 ROSE, D. A. (1967) Water transport in soils by evaporation and infiltration. *Proc. UNESCO Symposium*, Wageningen (1966). (In the press.)

The equation of vertical flow is adapted to describe the evaporation of water from, and the uptake of water by, a deep uniform soil free from vegetation. The theory is examined by laboratory measurements on long columns of 0·5–1·0 mm aggregates of three soils from Rothamsted and Woburn.

Evaporation from soils initially at a uniform moisture content—field-capacity—decreases as the square root of time, and causes moisture profiles invariant with $zt^{-\frac{1}{2}}$ (where z = depth below soil surface, and t = time), which differ for each soil. Drying diffusivities calculated from these profiles have an unusual shape, decreasing to a minimum and then increasing as the moisture content (θ) decreases from field-capacity to air-dryness. The uptake of water treated in the same way yields wetting diffusivities that also display a prominent minimum as θ increases from air-dryness to field-capacity.

The shape of these diffusivity–moisture-content relations is discussed and the concept of sorptivity adapted to yield a parameter specifying the water-supplying power of a soil when evaporation is limited by soil moisture.

Chemistry Department

BOOK

2.1 COOKE, G. W. (1967) *The control of soil fertility*. London: Crosby Lockwood, xvii, 526 pp.

THESES

2.2 COULTER, B. S. (1966) The exchange of aluminium in soils and clays by calcium, potassium and hydrogen ions. Ph.D. Thesis, University of London.

2.3 DEIST, J. (1966) Cation exchange equilibria and kinetics in soils and clay minerals with particular reference to potassium in the cation pairs K–Ca, K–Na and K–Rb. Ph.D. Thesis, University of London.

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2.4 WEBBER, M. D. (1966) Studies on inorganic soil phosphate with special reference to: I. Changes in phosphate potential on cropping; II. Evidence for the stability of basic calcium phosphates. Ph.D. Thesis, University of London.

GENERAL PAPERS

2.5 BENZIAN, B. (1966) Nutrition experiments in forest nurseries. *Q. Jl For.* **60**, 94–100.

2.6 BENZIAN, B. (1966) Risk of damage from certain fertilizer salts to transplants of Norway spruce and the use of slow-release fertilizers. *Forestry* (*Suppl.: Physiology in Forestry*), 65–69.

2.7 BENZIAN, B. (1966) Manuring young conifers: experiments in some English nurseries. *Proc. Fertil. Soc.* No. 94, 1–35.

2.8 BENZIAN, B., BOLTON, J. & MATTINGLY, G. E. G. (1966) Nutrition experiments in forest nurseries: Slow-release fertilizers for conifer seedlings. *Rep. Forest Res., Lond.* for 1965, 88–89.

2.9 BOLTON, J. & COULTER, J. K. (1966) Distribution of fertilizer residues in a forest nursery manuring experiment on a sandy podzol at Wareham, Dorset. *Rep. Forest Res., Lond.* for 1965, 90–92.

2.10 COOKE, G. W. (1965) The responses of crops to phosphate fertilizers in relation to soluble phosphorus in soils. *Tech. Bull. Minist. Agric. Fish. Fd* No. 13, Soil Phosphorus, London: H.M.S.O., pp. 64–74.

2.11 COOKE, G. W. (1966) Phosphorus and potassium fertilisers: their forms and their places in agriculture. *Proc. Fertil. Soc.* No. 92, 1–37.

2.12 COOKE, G. W. (1966) Soils and fertilisers. *Jl R. agric. Soc.* **127**, 128–145.

2.13 COOKE, G. W. (1966) The relationship of the classification of soils with their properties and fertility. (In Bulgarian) *Soil Sci. Agrochem.* **1**, 121–133.

2.14 COOKE, G. W. (1966) The chemical control of soil fertility. (In Bulgarian) *Soil Sci. Agrochem.* **1**, 209–229.

2.15 COOKE, G. W. (1966) Taking the brake off cereal yields. *Arable Fmr* **1**, No. 1, 10–12.

2.16 COOKE, G. W. (1966) Fit the fertiliser to the crop. *Fmr Stk Breed.* 26 April, 45–46.

2.17 COOKE, G. W. (1966) Fit dressings to soil and system. *Farming World* 25 August.

2.18 COOKE, G. W. (1966) The availability of plant nutrients in soils and their uptake by crops. *Fertil. Feed. Stuffs J.* **63**, 823–824, 827.

2.19 COOKE, G. W. (1967) The availability of plant nutrients in soils and their uptake by crops. *Rep. E. Malling Res. Stn* for 1966, 48–69.

2.20 DRAYCOTT, A. P. & COOKE, G. W. (1966) The effects of potassium fertilisers on quality of sugar beet. *Potass. Symp.* 1966.
(For Summary see No. 16.6)

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2.21 GASSER, J. K. R. (1965) Soils. *Rep. Progr. appl. Chem.* **50**, 201–212.

2.22 GASSER, J. K. R. & WIDDOWSON, F. V. (1966) Ammonia as a fertiliser. *J. Inst. Corn agric. Merch.* **14**, 130–133, 143.

2.23 MATTINGLY, G. E. G. (1966) Residual value of cumulative dressings of superphosphate, rock phosphate and basic slag on a sandy soil at Wareham, Dorset. *Rep. For. Res., Lond.* for 1965, 93–96.

2.24 MATTINGLY, G. E. G. & TALIBUDEEN, O. (1967) Progress in the chemistry of fertilizer and soil phosphorus. *Topics Phosphorus Chem.* **4**, 157–290.

2.25 WARREN, R. G. & COOKE, G. W. (1965) Comparison between methods of measuring soluble phosphorus and potassium in soils used for fertiliser experiments on sugar beet. *Tech. Bull. Minist. Agric. Fish. Fd* No. 13, Soil Phosphorus, London: H.M.S.O., pp. 75–83.

2.26 WARREN, R. G. & JOHNSTON, A. E. (1965) Notes on the use of soil analysis for estimating available P in Rothamsted soils. *Tech. Bull. Minist. Agric. Fish. Fd* No. 13, Soil Phosphorus, London: H.M.S.O., pp. 30–37.

2.27 WILLIAMS, R. J. B. & COOKE, G. W. (1965) Measuring soluble phosphorus in soils, comparisons of methods, and interpretation of results. *Tech. Bull. Minist. Agric. Fish. Fd* No. 13, Soil Phosphorus, London: H.M.S.O., pp. 84–92.

RESEARCH PAPERS

2.28 GARBOUCHEV, I. P. (1966) Changes occurring during a year in the soluble phosphorus and potassium in soil under crops in rotation experiments at Rothamsted, Woburn and Saxmundham. *J. agric. Sci., Camb.* **66**, 399–412.

From May 1963 to April 1964 seasonal changes in soluble nutrients were followed in soil samples taken monthly from plots having none, PK and NPK fertilisers in experiments at Rothamsted and Woburn. Phosphorus, potassium and magnesium concentrations in equilibrium extracts of the soils made with 0·01*M*-$CaCl_2$ solutions were determined. Exchangeable P was determined with an anion exchange resin. Samples were taken from under five arable crops growing in rotation, and under permanent grass on the two soils.

Concentrations of both P and K varied from month to month, but there was also a seasonal pattern of change, and under most crops they were greatest in the spring. This pattern was caused by applying fertiliser, uptake by crops and by the reactions that tend to restore equilibria between the forms of a plant nutrient in soil. In both soils soluble P and K were usually maximal in the spring of 1963 and were minimal just after the crops had been harvested; concentrations gradually increased during winter, and by spring of 1964 had mostly reached the original maxima. The size of crop grown affected the results; concentrations of both P and K in equilibrium extracts of NPK-treated plots fell below those of the PK-plots because the larger crops grown with N fertiliser took up more P and K. Herbage crops containing legumes were exceptions, as PK-treated plots yielded well because the clover fixed N. Minimum concentrations of P and K in the $CaCl_2$ extracts occurred later under those crops (kale, sugar beet and ley) that grew during late summer and autumn than under cereals or potatoes.

The P concentrations in $CaCl_2$ extracts changed proportionately more at

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Rothamsted than at Woburn; in contrast, exchangeable P varied little at Rothamsted during the year, but changed greatly in the light Woburn soil.

The differences between maximum and minimum P and K concentrations were large enough to be very important practically. Soluble P and K commonly varied by factors of two or three during the season; in a few plots maximum concentrations were four or five times larger than the minima.

Seasonal changes in concentrations of Mg in $CaCl_2$ extracts of soils were small. Ratios of the ion concentrations $K/\sqrt{Mg}$ were larger at Rothamsted than at Woburn, but at both they depended largely on the amounts of K dissolved.

Measurements on soil samples taken at four times in the year from a rotation experiment at Saxmundham (Suffolk) showed similar variations to those at Rothamsted and Woburn in concentrations of P and K in $CaCl_2$ extracts. Amounts decreased when crops were growing and increased again in winter. Concentrations of sodium in the solutions were larger in NPK-treated plots (where N was supplied as $NaNO_3$); they decreased during the year, presumably because of leaching and uptake by crops. Trends in nutrient concentrations were less regular at Saxmundham than at Rothamsted and Woburn. Sampling more often than once in 3 months is needed in such work.

2.29 HOYT, P. B. (1966) Chlorophyll-type compounds in soil. I. Their origin. *Pl. Soil* **25**, 167–180.

The amounts of chlorophyll-type compounds in materials commonly deposited on or in soil were measured, and the processes that destroy them in materials on the soil surface, and the ways they may enter the soil, were studied. Of plant material commonly deposited on the soil, freshly cut ryegrass and lucerne contained most of such compounds and cereal straw least. Faeces from grazing cattle and sheep contained nearly as much as grass; farmyard manure contained only 5% as much as fresh faeces.

Nine-tenths of the chlorophyll in chopped-up, fresh ryegrass leaves was decomposed in 6 days; this decomposition was attributed to tissue enzymes and was prevented by boiling, drying, water-logging or freezing. Micro-organisms decomposed about 60% of chlorophyll in ryegrass leaves in 90 days.

A large amount of chlorophyll-type compounds in faeces on soil leached 4 in. deep into the soil during 90 days in the autumn. Soil under 100-year-old, grazed, pasture contained more of these compounds than under grassland that was cut for hay each year.

2.30 HOYT, P. B. (1966) Chlorophyll-type compounds in soil. II. Their decomposition. *Pl. Soil* **25**, 313–328.

The degradation of chlorophyll-type compounds (chlorophyll and its derivatives) in soil was followed by spectrophotometric and chromatographic techniques to find how closely they represent the bulk of plant material in soil. Tissue enzymes rapidly decomposed chlorophyll in chopped plant material mixed with soil, and decomposition was much slower in material in which the enzymes had been inactivated. This slow decomposition is by micro-organisms which seem to be the important cause of chlorophyll degradation in soil.

Micro-organisms decomposed both chlorophylls *a* and *b* in 2–4 months in field soils; chlorophyll *a* was attacked most. Of the chlorophyll-type compounds, pheophytin, the most closely related derivative of chlorophyll, resisted decomposition largest; chlorophyllide and pheophorbide were found rarely in soil and never in large amounts.

Microbiological decomposition increased with increasing moisture content of soil, was fastest at 50–60% of the water-holding capacity. Decomposition slowed with increasing soil acidity, and was very slow at pH below 4·0. Raising the

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temperature from 5° to 25° C increased the rate of degradation. Neither the species nor quantity of plant material had much effect on the rate of decomposition.

2.31 NEWMAN, A. C. D. (1966) The distillation of ammonia for isotopic analysis. *Chemy Ind.* 115–116.

When distilled in all-glass apparatus, microgramme quantities of ammonium were held up and recovered only after several distillations; in this way ^{15}N-labelled samples may become cross-contaminated. Hold-up was eliminated by substituting a silver tube condenser.

2.32 NEWMAN, A. C. D. & OLIVER, S. (1966) Isotopic exchange of fixed ammonium. *J. Soil Sci.* **17**, 159–174.

The isotope ^{15}N was used to study the rate of exchange between unlabelled NH_4-hydrobiotite and labelled solution NH_4.

Most of the isotopic dilution occurred within 10 minutes of adding the solution to the solid, but even after 13 days less mineral-NH_4 had exchanged with isotope than was removed by several extractions with KCl solution.

NH_4 remaining in the mineral after extraction with KCl, conventionally named "fixed ammonium", contained some isotope that was sorbed without release of unlabelled NH_4; the fixed ammonium was, therefore, not isotopically exchangeable. The sorption resulted from incomplete ammonium saturation of hydrobiotite, the isotope slowly replacing interlayer cations trapped by lattice collapse.

The rate of sorption was initially controlled by a temperature-dependent diffusion process for which the activation energies were between 9 and 13 kcal/mole. Later the reaction became progressively slower than predicted by the diffusion equation, and analysis of the kinetics suggested that, ultimately, exchange of cations at the sorption sites was the rate-limiting process.

2.33 NOWAKOWSKI, T. Z. & GASSER, J. K. R. (1967) The effect of a nitrification inhibitor on the concentration of nitrate in plants. *J. agric. Sci., Camb.* **68**, 131–133.

Calcium nitrate or ammonium sulphate without or with 1% of the nitrification inhibitor 2-chloro-6(trichloromethyl)pyridine were applied in the spring to winter wheat growing on clay- and sandy-loam soils; 50 or 100 lb N/acre was applied on the clay-loam and 75 or 100 lb N/acre on the sandy-loam. On permanent grassland ammonium nitrate or ammonium sulphate without or with 1 or 2% of inhibitor were broadcast to supply 100 or 200 lb N/acre. Winter wheat was sampled 32 days, and grass 68 days after applying fertilisers. Ammonium sulphate increased nitrate in the wheat on the clay-loam soil, but significantly less with than without the inhibitor. On the sandy-loam, wheat given ammonium sulphate with and without the inhibitor contained similar amounts of nitrate-N. The double amount of ammonium sulphate without inhibitor increased the nitrate content of grass most, and the nitrate content decreased with increasing amount of inhibitor.

2.34 NOWAKOWSKI, T. Z., NEWMAN, A. C. D. & PENNY, A. (1967) The effect of different nitrogenous fertilisers applied as solids or solutions on dry matter yields and nitrogen uptake by grass. Part II. *J. agric. Sci., Camb.* **68**, 123–129.

Three field trials with Italian ryegrass showed that solid N fertilisers usually gave larger yields than solutions containing 5% N, but the differences were significant in only 3 of 13 comparisons. More N was taken up from solid fertilisers

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than from solutions; the differences were not significant at 56 lb N/acre, but were at 112 lb N/acre. Grass given solutions had smaller percentage of N, and the differences in the percentage of N were significant in 8 of 10 comparisons. In pot experiments with Italian ryegrass solutions containing 3·3% N were less effective than solid fertilisers, but solutions containing 1·8% N were equally effective. Possible causes of solutions being less effective are discussed.

2.35 RAWSON, R. A. G. (1966) Improvement in performance of a simple atomic absorptiometer by using pre-heated air and town gas. *Analyst* **91**, 630–637

A simple atomic absorptiometer for routinely determining magnesium, copper and zinc is described. A preheated air supply to the atomiser increased the response efficiency of the absorptiometer 16 fold. An adjustable slot in the burner enabled a wide range of fuel gases to be used. A horizontal monochromator slit improved light transmission and absorption.

2.36 TINKER, P. B. & BOLTON, J. (1966) Exchange equilibria of sodium on some British soils. *Nature, Lond.* **212**, 548.

Cation exchange relations between sodium and calcium plus magnesium were determined by equilibrating soils with a range of 0·01*M*-calcium chloride solutions containing different amounts of sodium. Graphs of sodium activity ratios in solution (AR^{Na}) against changes in adsorbed sodium (exch. Na) were mostly linear, but at small AR^{Na} values became asymptotic to the exch. Na axis for mineral soils but not for organic soils. Beckett (*Soil Sci.* **97**, 376 (1964)) proposed the presence of exchange sites "specific" for potassium adsorption to explain similar phenomena he observed for K : Ca + Mg exchange. The presence in mineral soils of a small proportion of exchange sites that adsorb sodium at a greater exchange energy than the rest of the exchange capacity is proposed to explain the form of the AR^{Na} : exch. Na graphs. These sites correspond to about 0·5% of the exchange capacity, but in most British soils with small exchangeable Na contents a significant proportion is adsorbed at large exchange energies.

2.37 WALKER, J. M. (1965) Electrical A.C. resistance and capacitance of Zea Mays L. *Pl. Soil* **23**, 270–273.

Some resistive and capacitive properties of growing maize plants were investigated. Rolled-leaf, stem and root tissue acted like cylindrical conductors and parallel-plate capacitors. The age of plants (up to 6 weeks) had little effect on the resistivity and dielectric properties of the maize tissues.

2.38 WIDDOWSON, F. V. & PENNY, A. (1966) Experiments comparing broadcast and combine-drilled dressings of several NPK fertilisers for spring barley. *Expl Husb.* No. 14, 93–97.

In 1961 three barley experiments measured yield with an NPK fertiliser (17% N; 11% P_2O_5; and 22% K_2O), either broadcast, combine-drilled or side-placed at amounts giving 0·3, 0·6 or 0·9 cwt N/acre. Yields were greatly increased by fertiliser and were slightly greater with drilled or side-placed than with broadcast dressings.

In 1963, 1964 and 1965 four experiments were made; they were on the same farms each year. Yields from broadcast, combine-drilled and partly combine-drilled dressings of several NPK fertilisers (with different % N : % P_2O_5 : % K_2O ratios) were compared.

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In 1963 20 : 10 : 10 and 10 : 10 : 10 were applied to give 0·3, 0·6 or 0·9 cwt N/acre. Yields were consistently larger with combine-drilled than with broadcast fertiliser; divided dressings gave intermediate yields. 10 : 10 : 10 gave larger yields than 20 : 10 : 10 in two-thirds of the comparisons.

In 1964 22 : 11 : 11, 18 : 18 : 9 and 18 : 18 : 18 were applied to give 0·45 or 0·90 cwt N/acre. Yields were larger with combine-drilled than with broadcast fertiliser at three centres; divided dressings were intermediate. Yields from the three fertilisers were similar.

In 1965 22 : 11 : 11, 18 : 18 : 18 (with KCl) and 18 : 18 : 18 (with KNO_3) were applied to give 0·45 or 0·90 cwt N/acre. Yields were larger with combine-drilled fertiliser at three centres; divided dressings were intermediate. Yields from the three fertilisers were not consistently different.

Mean gains (in 12 experiments) from combine-drilling over broadcasting were 2·2 cwt grain/acre, both when 0·45 and when 0·90 cwt N/acre were supplied by the fertilisers.

Grain % N was determined more by soil and season than by fertiliser. Applying 0·45 cwt N/acre or less increased % N only a little, but applying 0·90 cwt N/acre increased it proportionately much more. Percentage N was increased slightly more by drilled than by broadcast fertilisers, but it was not changed by the N : P_2O_5 : K_2O ratio in the fertiliser.

2.39 WIDDOWSON, F. V. & PENNY, A. (1967) Results of an experiment at Woburn testing farmyard manure and N, P and K fertilisers on five arable crops and a long ley. Part I. Yields. *J. agric. Sci., Camb.* **68**, 95–102.

In 1960 a "reference plot" experiment was begun on Stackyard field at Woburn, where arable crops had grown for many years. The soil contained very little N or HCl-soluble K and little HCl-soluble P; it was acid, but was limed before and during the experiment to a pH at or near 7·0. Very small plots (0·00145 acre) were used.

Responses to all combinations of N, P and K fertilisers and to farmyard manure (D) were measured during a five-course rotation of barley, grass–clover ley, potatoes, oats and sugar beet. Two amounts of N were compared with each crop. A block of long ley and one of soft fruit had the same test treatments.

Sugar beet yielded the most, and barley the least dry matter, both when they were unmanured and when they were given the largest dressing of manure (DN_2PK). Sugar-beet roots and the rotation ley each produced more dry matter per acre without fertilisers or FYM than barley or oats did with full manuring. Yields of the rotation ley were increased least, proportionally, by added nutrients.

All agricultural crops except the rotation ley responded well to N but only a little to P, which increased yields of potatoes and barley more than of oats, sugar beet or the leys. After a time all the crops responded to K; potatoes responded most, but sugar-beet roots (though not tops), the rotation ley and the long ley all responded greatly. Barley and oats needed K less and sugar-beet tops least of all. Positive interactions between nutrients were significant for sugar-beet roots (NK) and for the rotation ley (PK); there were no significant negative interactions.

FYM increased yields of all crops, but especially potatoes, sugar beet and the long ley. Residues from these dressings increased yields of the rotation ley more than of oats and barley. Responses to FYM were usually less when fertilisers also were given, but with sugar-beet roots and barley they remained nearly the same. A combination of FYM and fertiliser gave the largest yield of every crop.

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2.40 WIDDOWSON, F. V., PENNY, A. & WILLIAMS, R. J. B. (1966) An experiment measuring effects of N, P and K fertilisers on yield and N, P and K contents of grazed grass. *J. agric. Sci., Camb.* **67**, 121–128.

An experiment was started in 1959 to measure effects on grazed permanent grass of ammonium sulphate, calcium nitrate, superphosphate and muriate of potash; yields and N, P and K contents of the herbage were measured from 1961 to 1964.

Applying 1·5 cwt N/acre/year (in four bi-monthly doses) consistently increased yields. The first and fourth cuttings yielded less with 3·0 cwt N/acre/year (also in four bi-monthly doses) than with 1·5 cwt N/acre/year, but the second and third cuttings yielded more; the *total* additional yield from 3·0 cwt N was small. Yields were increased equally by ammonium sulphate (providing that lime was also applied) and calcium nitrate.

Yields were increased more by P than by K; the increase from P was greater when N was also applied.

Much more N was removed in the herbage from plots manured with N (though little clover was present) than was added in the N fertilisers.

Less P was removed in the herbage than was added (as superphosphate), but percentage P in the herbage decreased with time whether or not P was added.

Nearly twice as much K was removed in the herbage as was added (as muriate of potash); percentage K in the herbage decreased with time, especially when N but not K was applied.

Grass manured with calcium nitrate was preferred by the stock.

Unrestricted grazing did not spoil the comparisons made in the experiment.

Pedology Department

THESIS

3.1 GAD, M. A. M. A. (1966) A geochemical study of the Liassic rocks of the Yorkshire coast. Ph.D. Thesis, University of London.

GENERAL PAPERS

3.2 JENKINSON, D. S. (1966) The turnover of organic matter in soil. In: *The use of isotopes in soil organic matter studies.* Oxford: Pergamon Press, pp. 187–197.

3.3 JENKINSON, D. S. (1966) The priming action. In: *The use of isotopes in soil organic matter studies.* Oxford: Pergamon Press, pp. 199–208.

3.4 JENKINSON, D. S. (1966) Experimental techniques for using carbon-14 in studies of soil organic matter. In: *The use of isotopes in soil organic matter studies.* Oxford: Pergamon Press, pp. 365–369.

3.5 RAYNER, J. H. & BROWN, G. (1966) A triclinic form of talc. *Nature, Lond.* **212**, 1352–1353.

RESEARCH PAPERS

3.6 BROWN, G. & TAPP, C. J. (1966) Potassium-supplying power of some soil parent materials. In: The Soils of the Preston District of Lancashire. *Mem. Soil Surv. Gt. Br.* Appendix III, pp. 117–121.

The drift-derived parent materials of 23 important soil series mapped in the area covered by Sheet 75 were examined chemically and mineralogically. A

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positive correlation was found between the amount of potassium released when the soil was treated with 4*N*-hydrochloric acid and the proportion of clay-sized mica in the soil. The examinations also showed that the drifts were derived from two main sources, and the separations arrived at by field examination were broadly confirmed. The Triassic drifts, the clay fractions of which are richer in mica, give the soils to which they contribute a larger potassium-supplying power than that of the Carboniferous-derived materials.

3.7 CATT, J. A. & (PENNY, L. F.) (1966) The Pleistocene deposits of Holderness, East Yorkshire. *Proc. Yorks. geol. Soc.* **35**, 375–420.

The Holderness tills are described, and grouped into two series: the Basement Series below, and the Drab-Purple-Hessle Series above. The Basement Till is shown to underlie (and not overlie as was formerly supposed) the Sewerby raised beach, which is considered to belong to the Last Interglacial. The Basement Till was therefore deposited during the Saale Glaciation or earlier, and the Bridlington Crag (which has been rediscovered after being hidden for 60 years) may thus be of Holstein (Great Interglacial) age or earlier. The Drab-Purple-Hessle Series is considered to have been deposited from one composite ice sheet of Würm age, probably Main Würm, and the "moss silts" which underlie it at Dimlington are placed in a Würm interstadial. The early Würm may be represented by the solifluction bed at Sewerby. The Kelsey Hill Gravels, the Kirmington silts and the Speeton Shell Bed are reassessed, and their position in the chronology is discussed.

3.8 GAD, M. A. & LE RICHE, H. H. (1966) A method for separating the detrital and non-detrital fractions of the trace elements in reduced sediments. *Geochim. cosmochim. Acta* **30**, 841–846.

A new extraction technique is described for distinguishing detrital from non-detrital fractions of trace elements in reduced sediments. The material is treated with hydrogen peroxide, whereby sulphides are dissolved and organic matter partly destroyed. Subsequent treatment of the residue with acid ammonium oxalate in ultra-violet light dissolves some of the iron and aluminium. This treatment is compared with acetic acid as an extractant of trace elements in Lias shales.

3.9 HIMES, F. L. & BLOOMFIELD, C. (1966) Identification of two compounds in the benzene-methanol extract of a peat soil. *Pl. Soil.* **26**, 386.

Two compounds in the benzene–methanol extract of a peat soil were identified. The soil contained 0·2% Cu. The major component of a white waxy material that was isolated was triacontyl stearate. Copper pheophytin *a* was also identified, but this was shown to be an artefact formed during the extraction.

3.10 JENKINSON, D. S. (1966) Studies on the decomposition of plant material in soil. II. Partial sterilisation of soil and the soil biomass. *J. Soil Sci.* **17**, 280–302.

Soil samples taken during an experiment on the decomposition of ^{14}C-labelled ryegrass in soil under field conditions (see Part I) were air-dried, irradiated, exposed to $CHCl_3$ or CH_3Br vapours, oven-dried or autoclaved. After these treatments the soils were inoculated, incubated and the output of CO_2 measured. All these methods of partially (or completely) sterilising soil rendered a small heavily labelled fraction of the soil organic matter decomposable. This fraction is postulated to be the soil biomass. Treatments involving heat or irradiation rendered small additional amounts of the soil organic matter decomposable (by processes other than the killing of organisms).

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Incubating unsterilised soil with partially sterilised soil did not decrease evolution of CO_2. This suggests that partial sterilisation does not increase mineralisation by destroying toxic substances that inhibit microbial growth, or by disturbing a host : predator balance in the unsterilised soil.

The longer the labelled ryegrass was allowed to decompose in the field, the less labelled-CO_2 was evolved after partial sterilisation. In contrast, the same amount of unlabelled-CO_2 was evolved from a soil that had been incubated 1 or 4 years with ryegrass. The labelled part of the biomass is considered to be largely zymogenic (with a half life of approximately 1·5 years), the unlabelled part largely autochthonous, remaining almost constant over the 3-year period.

It is suggested that the size of the soil biomass can be *roughly* estimated from the size of the flush of CO_2 after $CHCl_3$ vapour treatment. Calculated on this basis, 2·3–3·5% of the unlabelled-C in these soils (i.e. the C present in the soil before the labelled ryegrass was added) was in the biomass. Of the original ryegrass C added, 10–12% was in the biomass after 1 year, decreasing to 4% after 4 years.

3.11 KING, H. G. C. (1966) Leucoanthocyanins from the leaves of European larch (*Larix decidua* (Mill). *Nature, Lond.* **211**, 944–945.

A hitherto unknown water-soluble leucodelphinidin is co-precipitated with an insoluble calcium compound when an aqueous extract of larch leaves is allowed to stand. The leucodelphinidin is substituted, probably in the 4′ position, with a disaccharide consisting of glucose and arabinose. The leucodelphinidin and the calcium compound together constitute 2–3% of the dry weight of the leaves, corresponding to 10–15% of the aqueous extract.

Delphinidin, cyanidin and an unknown anthocyanidin were extracted from the leaves by boiling alcoholic HCl.

3.12 KING, H. G. C. & PRUDEN, G. (1967) The component of commercial Titan yellow most reactive towards magnesium: its isolation and use in determining magnesium in silicate minerals. *Analyst, Lond.* **92**, 83–90.

The component of Titan yellow most reactive towards magnesium was isolated from the acetone-extracted dye by adsorption chromatography on "Sephadex G-10". It can be used at a concentration as small as 0·008%, at which concentration the response is linear between 20 and 150 μg Mg.

3.13 NEWMAN, A. C. D. & BROWN, G. (1966) Chemical changes during the alteration of micas. *Clay Min.* **6**, 297–310.

Di- and tri-octahedral micas were altered to vermiculite-like minerals by extracting the K with sodium tetraphenylboron. Chemical analysis of original and altered micas shows that loss of K is accompanied by an increased loss on ignition, oxidation of some Fe^{2+} to Fe^{3+}, loss of divalent octahedral cations, mainly Mg^{2+}, loss of OH^- (or sorption of H^+) and decrease in net negative charge.

The following reactions are suggested to explain these changes:

(1) replacement of K by Na at interlayer sites;

(2) release of structural OH^- ions exposed by replacement of K, which decreases the negative charge and allows the structure to expand and more K to be replaced;

(3) oxidation of Fe^{2+} ions by the reaction $4\ Fe^{2+} + 4$ structural $(OH^-) + O_2 \longrightarrow 4\ Fe^{3+} + 4$ structural $(O^{2-}) + 2H_2O$;

(4) release of divalent octahedral ions, possibly through some of the holes left when structural OH^- is lost.

The wide implications of these proposals are discussed.

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Soil Microbiology Department

General Paper

4.1 Walker, N. (1967) Soil micro-organisms and plant protection chemicals. In: *Soil biology*, ed. N. A. Burgess & F. Raw. London: Academic Press, Chapter 17, pp. 493–503.

Research Papers

4.2 Darbyshire, J. F. (1966) Studies on the physiology of nodule formation. IX. The influence of combined nitrogen, glucose, light intensity and day length on root-hair infection in clover. *Ann. Bot.* **30**, 623–638.

Small amounts of nitrate or nitrite salts (10 μg N/plant) in the root medium of *Trifolium glomeratum* or *T. repens* delayed nodulation, prolonged the initial rapid phase of root infection and slightly stimulated lateral root formation, whereas equivalent quantities of ammonium sulphate or urea did not. Growth of roots and root hairs was unaffected by any of these substances at 10 μg/N/plant.

Altering the carbohydrate status of the clover seedlings by adding glucose to the root medium or by changing day length or light intensity influenced neither the stimulation of root-hair infection nor the delay in nodulation induced by nitrate at 10 μg N/plant, except that plants grown in total darkness had fewer hairs infected when the root medium contained small amounts of nitrate. The nitrogenous compounds at 100 μg N/plant generally delayed and decreased nodulation, increased lateral root formation, slowed hair infection and increased root growth.

4.3 Festenstein, G. N., Gregory, P. H., Lacey, J. & Skinner, F. A. (1966) The microbiology of mouldy hay. *Proc. R. Soc. Med.* **59**, 1007–1008. (For summary see No. 6.20)

4.4 Jackson, R. M. & Brown, M. E. (1966) Behaviour of Azobacter chroococcum introduced into the plant rhizosphere. *Ann. Inst. Pasteur, Paris.* **111**, Suppl. 112–113.

The behaviour of *Azotobacter chroococcum* during germination of inoculated seed in unsterile soil or potting compost was studied. The inoculum consisted of encysted cells, and these germinated in the seed and seedling root regions, but not in soil away from seedlings. Movement of inoculum from the seed on to the the roots was followed by direct counting and by a root-mapping technique. Isolations from serial washings showed that some cells of *Azotobacter* are in close contact with the root surface. The inoculum multiplied in the root zone of peas growing in unsterile potting compost.

4.5 Nutman, P. S. (1967) Varietal differences in the nodulation of subterranean clover. *Aust. J. agric. Res.* **18**, 381–425.

The pattern of nodule formation (time of formation, number and size) was examined in 15 varieties of subterranean clover and in some tetraploid and hybrid lines. Nodulation time differed slightly between varieties, but was more influenced by bacterial strain; it was not affected by host ploidy. Average nodule number varied up to six times between host varieties and was less on tetraploids than diploids. The habit of abundant nodule formation was dominant over sparse nodulation in hybrids, and selection in subsequent selfed generation increased mean nodule number above that of the abundant parent. Selection for sparseness usually failed to decrease nodule number below that of the sparse

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parent. Usually varietal nodule number and lateral root number were correlated and the proportion of nodules borne on lateral roots was greater on abundantly nodulating varieties.

Nodule number and average nodule length (and average nodule diameter) were related hyperbolically. Aggregate nodule length tended to a constant value that was somewhat larger for abundantly nodulating lines. The effectively nodulated plant bears substantially the same amount of persistent bacteroid tissue irrespective of the number of nodules formed, and this fixes nitrogen at the rate of 22 μg N/mm³ tissue per day. The relative volumes of the nodule's meristem, cortex and infected zones were only slightly affected by selection for nodule number and were independent of bacterial strain. The proportion of degenerate bacteroid tissue was much larger with the ineffective bacterial strain ClF than with the effective strain Su297.

Botany Department

General Papers

5.1 Goodman, P. J. (1966) Effect of varying plant populations on growth and yield of sugar beet. *Agric. Prog.* **41.** (In the press.)

5.2 Humphries, E. C. (1966) Prospects for CCC. *Arable Fmr* Dec. 8–9.

5.3 Humphries, E. C. (1967) Some general properties of growth regulators and their potential use in agriculture. *Agric. Prog.* **42.** (In the press.)

Research Papers

5.4 (Allison, J. C. S.) & Watson, D. J. (1966) The production and distribution of dry matter in maize after flowering. *Ann. Bot.* **30,** 365–381.

An experiment in which different groups of leaf laminae were removed, or ears shaded, shortly after silking showed that most of the dry-matter increase after flowering was produced by upper leaves. The sheaths provided about one-fifth of the total leaf area and probably contributed about one-fifth, and laminae four-fifths, of the total dry matter produced after flowering. The contribution from photosynthesis by the ear was negligible, presumably because its surface area was only 2% of that of the leaves. Leaf efficiency (dry matter produced per unit area) decreased greatly from the top to the base of the shoot. When laminae were removed the grain received a larger fraction of the dry matter accumulated after flowering, less dry matter remained in the stem and the photosynthetic efficiency of the remaining leaves was apparently increased.

When alternate laminae were removed at the time of silking (half-defoliation) D was decreased by 40%, and the subsequent production of dry matter decreased nearly proportionately, so that net assimilation rate (E) was not affected but grain dry weight was decreased by only 32%. Stem weight decreased from 2 weeks after flowering in half-defoliated plants, but remained nearly constant in intact plants. When pollination was prevented and no grains formed, E during the first month after flowering was unaffected; the dry matter that would have passed into the grain accumulated in the stem and husks, not in the leaves.

5.5 Dyson, P. W. & Humphries, E. C. (1966) Modification of growth habit of Majestic potato by growth regulators applied at different times. *Ann. appl. Biol.* **58,** 171–182.

The effect of gibberellic acid, CCC (2-chloroethyl-trimethylammonium chloride) and B9 (N-dimethylaminosuccinamic acid) on growth of potato plants was

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studied in pots. Growth was analysed on four occasions and changes in habit defined in terms of internode lengths, leaf areas and growth of lateral branches.

Soaking seed pieces for 1 hour in GA solution caused six internodes to elongate greatly, and this was not prevented by CCC applied when the shoot emerged from the soil. The effects on internode extension were dependent on the length of the interval between GA treatment and CCC treatment.

Treatment at emergence with CCC shortened all internodes, and more CCC applied 4 weeks later had no effect. Late applications of CCC or B9 shortened the top two lateral branches, which are usually very long in untreated plants.

The regulators usually affected leaf growth less than internode growth.

Effects on growth depended on when the regulators were applied. Treatment with GA alone inhibited bud development at higher nodes than in untreated plants; when followed by late treatment with CCC, lateral growth at higher nodes was also less. CCC retarded development of lateral branches, especially when applied early. B9 had a similar effect to that of CCC applied late. When regulators retarded growth of lower laterals upper laterals often grew more than in untreated plants. Treatments did not affect the number of leaves on the main stem at first, but later GA hastened senescence. GA increased the number of leaves on lateral stems, and the effect was enhanced by CCC. CCC alone increased the number of first- and second-order lateral leaves. GA lengthened and CCC shortened stolons. The effect of CCC persisted throughout the life of the plant. CCC or B9 shortened stolons whenever applied. CCC hastened tuber initiation but slowed tuber growth.

CCC at first retarded formation of lateral tubers but had no effect on the ultimate numbers of lateral and terminal tubers.

The net assimilation rate (E) did not alter with time. CCC applied at emergence increased E, probably because it hastened tuber initiation and temporarily increased sink capacity. Although tubers formed earlier with CCC, their growth was slower and their demand for carbohydrate was also less. The increase in second-order laterals on CCC-treated plants utilised carbohydrate that would normally go to tubers.

This experiment also demonstrates that crowding leaves by shortening stems did not diminish E, possibly because another over-riding process (bigger sinks) offsets the effect of shading.

5.6 HUMPHRIES, E. C. (1966) Internal control of rate of leaf production in sugar beet. *Physiologia Pl.* **19**, 827–829.

The theory that the rate at which leaves appear is little affected by the current environment was tested with sugar-beet plants. Seedlings were raised under four different conditions: 8-hour photoperiod 20° C, 16-hour photoperiod 20° C, in continuous light or in the glasshouse. After 2 weeks all were put in the glasshouse in the same growing conditions. The treatments applied to seedlings continued to affect the rate leaves were produced during the next 20 weeks.

5.7 HUMPHRIES, E. C. (1967) Leaf growth of white mustard (*Sinapis alba*) in different environments. *Planta* **72**, 223–231.

The numbers of cells and area of fully expanded leaves were determined on successive leaves of *Sinapis alba* grown either in 8-hour photoperiod (vegetative plants) or 16-hour photoperiod (flowering plants) at a constant temperature of 20° C. In the 8-hour photoperiod leaf 9 had the greatest area, but leaf 12 most cells. In the 16-hour photoperiod leaf 5 had the greatest area, but leaf 9 most cells. The relationship between area and cell number of successive leaves on the main stem fell into three distinct phases: (1) cell number increased faster than leaf area; (2) leaf area decreased while cell number increased; (3) cell number and

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leaf area decreased proportionally. For an increase in unit area, cell number increased more in 8-hour than in 16-hour photoperiod.

Using final area and final cell number of successive leaves, the cell number of unit area of primordium was deduced by extrapolation. Cell number per unit area increased in successive primordia up to a certain node, after which it remained constant at succeeding nodes. In plants grown under different conditions, the cell number per unit area in successive primordia increased at a constant logarithmic rate. That is, cells became progressively smaller. It is concluded that changes in cell size of successive primordia are not influenced by the environment but are under internal control.

5.8 HUMPHRIES, E. C. (1967) The effect of different root temperatures on dry matter and carbohydrate changes in rooted leaves of *Phaseolus* spp. *Ann. Bot.* **31**, 59–69.

The dry matter was estimated weekly in rooted dwarf-bean leaves (*Phaseolus vulgaris*) and runner-bean leaves (*Phaseolus multiflorus*) with roots held at 13°, 17°, 21° or 25° C. Most dry matter accumulated in the lamina of both species at the coldest root temperature. Roots of runner bean grew more than dwarf bean at all temperatures compared, especially at 13° and 17° C, and the greater net assimilation rate, i.e. dry matter increase per dm^2 per week of runner-bean leaves at cold temperatures, is attributed to faster root growth.

Shading lessened accumulation in the lamina, especially at cold root temperatures, because a greater proportion of assimilate was transferred to roots.

Rates of root growth are mainly influenced by temperature, and no effect of carbohydrate accumulation in the lamina at cold temperatures on root growth could be detected after the roots were kept warmer. Water content of the lamina per unit area increased as dry matter increased. For any particular dry-matter content the water content was greater with roots at 20° than at 13°, i.e. the leaves were more succulent with warmer roots.

When roots first formed on the petioles the lamina lost sugar and subsequently regained it, faster when roots were cold. When transferred from warm to cold root temperature, sugars accumulated in the lamina. Starch changed more than sugars in response to changing root temperatures. Starch in the lamina progressively declined when roots were warm, but increased when they were cold. The starch content of the lamina was rapidly influenced by root temperature. Sugars and starch together account for less than half of the dry matter increase in the lamina. The unidentified fraction is little influenced by changes of root temperature; it may be largely structural because the palisade cells continued to grow after the leaves were excised, although the lamina was fully expanded before the leaves were rooted. Palisade cells were larger with roots at 20° than at 13° C.

5.9 ORCHARD, B. (1967) A radiation-cooled growth cabinet. *J. agric. Engng Res.* **12**, 62–65.

A plant growth chamber, cooled by radiative heat transfer, is described. It has been used to minimise water loss from growing plants. Alternative uses and further developments are considered.

5.10 ORCHARD, B. (1967) Water deficit and the growth of crop seedlings. I. The effect of rate of change of soil water content on kale seedlings. *J. exp. Bot.* **18**, 308–320.

Leaf growth of kale seedlings was compared over a range of soil-moisture contents during a single drying cycle in several constant environments. With the particular soil and environments used, and when senescence effects were eli-

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minated, relative leaf growth rate was a linear function of soil-moisture percentage in the range equivalent to pF 1·7–4·2. The relationship was independent of differences in the rate of change of soil moisture resulting from changes in atmospheric humidity or in the ratio of leaf area to amount of water in the soil mass. Nevertheless, small changes in the rate of water loss integrated over a period can have relatively large effects on yield.

5.11 THORNE, G. N., FORD, M. A. & WATSON, D. J. (1967) Effects of temperature variation at different times on growth and yield of sugar beet and barley. *Ann. Bot.* **31**, 71–101.

Sugar beet and barley were grown in pots outdoors (environment N) and, for five successive 4-week periods starting at sowing, batches of plants were transferred to three growth rooms whose temperatures were either similar to the outdoor mean (environment M) or 3° C hotter (environment H) or 3° C colder (environment C). Some plants were harvested immediately after treatment; others were returned to environment N and harvested when mature.

At the end of period 1 sugar-beet plants from environment M had more dry weight and leaf area than those outdoors. Immediately after spending later periods in environment M, plants had smaller leaves but similar dry weight to those continuously outdoors. These differences disappeared by maturity. Warmth in the growth rooms (i.e. the difference H — C) during periods 1, 2 and 3, while leaf area was increasing, increased the number and size of leaves and usually also dry weight; in later periods it had no effect. The effects induced during periods 2 and 3, but not period 1, persisted to maturity to give greater total and root dry weight and yield of sugar. The final effects on dry weight were much larger than those immediately after treatment, because of differences in growth outdoors after treatment, which depended on differences in leaf area; the efficiency of the leaves was not affected by previous treatment.

Transferring barley to environment M from N had inconsistent immediate effects on leaf area and dry weight, and these disappeared by the final harvest. Transfer during periods 2 and 3, before the ears had started emerging, increased shoot number and delayed development. The proportion of the ears that ripened, and the yield of grain, was usually less for plants that had spent a period in environment M than for plants permanently outdoors which also had some green ears. Warmth in the growth rooms during periods 1 and 2 increased dry weight and leaf area immediately, but had negligible effects at maturity because the increases in leaf area did not persist after ear emergence. Warmth later hastened death of leaves, decreased total dry weight immediately and also at maturity, but increased the proportion of ears that ripened, and hence usually grain weight. Variation in leaf-area duration after ear emergence (D), determined by effects on the time the ears emerged and the rate the leaves died, accounted for most of the variation in grain yield, but warmth after the ears emerged decreased grain yield less than proportionally to the decrease in D.

5.12 WATSON, D. J., WILSON, J. H., FORD, M. A. & FRENCH, S. A. W. (1966) Changes with age in the photosynthetic and respiratory components of the net assimilation rates of sugar beet and wheat. *New Phytol.* **65**, 500–508.

The net assimilation rates (E) of sugar beet and wheat growing in a controlled environment, and their components, the rates of photosynthesis (P) and respiration (R) of the whole plant per unit leaf area, were determined at intervals by a method described previously that depends on measuring the decrease in E when photosynthesis is prevented on some days during an experimental period by keeping plants in darkness. An alternative method of changing the duration of

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photosynthesis, by shortening the daily photoperiod, gave estimates of P and R almost identical with those obtained by shading plants throughout some days.

In a period of 50 days from sowing for wheat and 90 days for sugar beet, E decreased by about a half. The value of P was always much greater than R; the smallest ratio of P to R was 5. Most of the decrease in E with age was caused by decrease in P, and the change in R with age was relatively small. At 30 days after sowing E of sugar beet was twice that of wheat, wholly because of difference in P. These experiments confirm that, except perhaps in extreme conditions, change in E can safely be attributed to change in photosynthetic rate.

5.13 WHEELER, A. W. (1966) Effect of removing cotyledons, apical growing region, or trifoliate leaves on the growth and growth-substance content of dwarf French bean (*Phaseolus vulgaris*). *J. exp. Bot.* **17**, 621–626.

The growth of the primary leaf on intact plants was compared with that on plants from which the cotyledons, apical growing region or trifoliate leaves had been removed. Removing the cotyledons early decreased the final area of the primary leaves, partly by decreasing cell number, and increased the concentration, but not the quantity, of gibberellin and auxin in them. This response was unaffected by applying any of several growth substances. Early removal of the apical growing region increased the final area of the primary leaves and their gibberellin content and concentration, but did not influence their auxin content and concentration. Primary leaf expansion was affected less by detaching young trifoliate leaves than by removing the entire apical growing region.

Biochemistry Department

GENERAL PAPERS

6.1 PIRIE, N. W. (1966) Fodder fractionation: an aspect of conservation. *Fertil. Feed. Stuffs J.* **63**, 119–122.

6.2 PIRIE, N. W. (1966) Towards the seleno-microcosm. *New Scient.* **30**, 574–576.

6.3 PIRIE, N. W. (1966) Leaf protein as a human food. *Science, N.Y.* **152**, 1701–1705.

6.4 PIRIE, N. W. (1966) The merits of food proteins from novel sources. *Sci. Progr., Lond.* **54**, 401–412.

6.5 PIRIE, N. W. (1966) Report on the working group meeting on novel protein sources: Warsaw 1966. *I.B.P. News* **7**, 82–84.

6.6 PIRIE, N. W. (1966) John Burdon Sanderson Haldane 1892–1964. *Biogr. Mem. Fellows R. Soc.* **12**, 219–249.

6.7 PIRIE, N. W. (1967) Science and development. In: The politics of science. *Political Quarterly* **38**, 62–71.

6.8 PIRIE, N. W. (1967) Space research and human needs. *UNESCO Features* **496**, 14–16.

6.9 PIRIE, N. W. (1967) The purpose and function of the International Biological Programme. *Proc. Nutr. Soc.* **26**, 125.

6.10 PIRIE, N. W. (1967) Orthodox and unorthodox methods for meeting the world's food needs. *Scient. Am.* **216**, 27–35.

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Research Papers

6.11 Bacon, M. F. (1965) Analysis of DNA preparations by a variation of the cysteine-sulphuric acid test. *Analyt. Biochem.* **13**, 223–228.

DNA can be estimated by reaction with sulphuric acid in the presence of chloride ions. The intensity of absorption, at 472 nm, depends on chloride-ion concentration; cysteine is not necessary for the reaction. The extent of contamination by RNA and aldohexose can be approximately estimated by comparing the spectra obtained before and after adding cysteine.

6.12 Bacon, M. F. (1966) Artefacts from chromatography of chlorophylls. *Biochem. J.* **101**, 34C–36C.

Chlorophylls *a* and *b* can each be rapidly converted into several "changed" chlorophylls by chromatography on thin layers of silica gel. These pigments, which are probably formed by oxidation, can also be produced in smaller amounts on Celite, kieselguhr G and Whatman No. 1 paper. They are probably the same as unusual chlorophylls reported to be present in extracts of *Chlorella* and ripening green peppers. The "changed" chlorophylls are less readily formed during thin-layer chromatography on cellulose powder, and this is suitable for checking the results of chromatography on other adsorbents. Traces of an impurity in diethyl ether used in this investigation caused phase-negative pigments to give ambiguous reactions in the Molisch phase test for integrity of the cyclopentanone ring.

6.13 Bacon, M. F. & Holden, M. (1967) Changes in chlorophylls resulting from various chemical and physical treatments of leaves and leaf extracts. *Phytochem.* **6**, 193–210.

Chlorophylls *a* and *b* are easily altered chemically when leaves or leaf extracts are exposed to treatments that include heating and the action of organic solvents. Monitoring by thin-layer chromatography on cellulose assists in detecting the chlorophyll derivatives. In addition to loss of magnesium, formation of chlorophyllides and the *a′* and *b′* isomers, and loss of colour, chlorophylls *a* and *b* can each be converted into two other derivatives, with absorption spectra almost identical with those of the parent compounds. The conditions of formation, purification and some of the properties of these derivatives are described, and possible structures are discussed.

6.14 Byers, M. (1967) The *in vitro* hydrolysis of leaf proteins. I. The action of papain on protein extracted from the leaves of *Zea mays*. *J. Sci. Fd Agric.* **18**, 28–33.

Maize leaf protein is not digested by papain at 37° C, under conditions in which casein is hydrolysed. An increase in temperature has more effect on both the initial rate of reaction and the final amount of hydrolysis than an increase in enzyme concentration. Maximum digestion is observed at pH 6·6 and 70° C using KCN-activated papain: 70% of the substrate N is hydrolysed to non-protein N. De-fatting of the protein by neutral solvent mixtures only slightly increases digestion.

Soluble N-containing fractions precipitable by TCA occur at all pH values, but most at pH 7·5 and above. Digestion leads to almost complete solution of the leaf protein at pH 8·6, but the percentage of hydrolysis never exceeds that at pH 6·6. These soluble fractions resemble those found in similar digests of seed proteins.

Though *in vivo* experiments show that protein made from mature wheat leaves has more nutritive value than protein from young leaves, there is no

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corresponding increase in the *in vitro* digestibility of protein extracted from maize leaves of increasing maturity.

6.15 BYERS, M. (1967) The *in vitro* hydrolysis of leaf proteins. II. The action of papain on protein concentrates extracted from leaves of different species. *J. Sci. Fd Agric.* **18**, 33–38.

The *in vitro* digestion by papain of protein concentrates extracted from 14 different species of leaves is described. The extent of hydrolysis varies with species and is probably influenced by preparative technique. The effect of leaf age is less certain: most proteins made by the current standard procedure from any one species, at all stages of growth, have similar digestibilities, but the digestibility of some preparations from mature leaves is less *in vitro*, but more *in vivo*, than is that of preparations from young leaves.

The hydrolysis of some fractionated proteins, prepared by controlled heating of leaf extracts, is also described. For all the species examined the "chloroplastic" fraction is digested less, and the "cytoplasmic" fraction more, than the corresponding whole protein: these results agree with those previously obtained *in vivo*. Differences in the N contents and *in vitro* digestibility of laboratory-prepared fractions, and those made on a large scale are discussed. Simulated whole protein, made by combining "chloroplastic" and "cytoplasmic" fractions in the correct proportions, is not hydrolysed to the same extent as the corresponding whole concentrate.

The percentages of "chloroplastic" and "cytoplasmic" protein, made by the method described here, varies with species, but the ratio seems not to alter as the leaf matures; this could explain the consistent *in vitro* results usually obtained with recent preparations, irrespective of leaf age. It is suggested that protein digestibility could be assessed rapidly by the method described here as a preliminary to the more thorough, but slower, *in vivo* tests.

6.16 CLARKE, A. J. & SHEPHERD, A. M. (1966) Picrolonic acid as a hatching agent for the potato cyst nematode *Heterodera rostochiensis*. *Nature, Lond.* **211**, 546.
(For summary see No. 8.5)

6.17 CLARKE, A. J. & SHEPHERD, A. M. (1966) Inorganic ions and the hatching of Heterodera spp. *Ann. appl. Biol.* **58**, 497–508.
(For summary see No. 8.6)

6.18 CLARKE, A. J. & SHEPHERD, A. M. (1966) Flavianic acid as a hatching agent for the cabbage cyst nematode, *Heterodera cruciferae* Franklin, and other cyst nematodes. *Nature, Lond.* **213**, 419–420.
(For summary see No. *Nature, Lond.* 8.7)

6.19 FESTENSTEIN, G. N. (1966) Biochemical changes during moulding of self-heated hay in Dewar flasks. *J. Sci. Fd Agric.* **17**, 130–133.

Moulding of hay was studied on samples moistened to 40% water content and allowed to heat aerobically in Dewar flasks. Reducing sugar, particularly glucose, decreased, and there were increases in pH and in soluble and volatile N. Smaller increases in soluble and volatile N, as well as the conversion of non-reducing to reducing sugar, occurred in moistened, sterile hay incubated at 40° C; these are analogous to changes during moist wilting of grass. Invertase activity in the hay was confirmed by incubation with sucrose and water.

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6.20 FESTENSTEIN, G. N., GREGORY, P. H., LACEY, J. & SKINNER, F. A. (1966) The microbiology of mouldy hay. *Proc. R. Soc. Med.* **59**, 1007–1008.

Mouldy hay associated with farmer's lung disease contained many spores of thermophilic moulds and actinomycetes, especially streptomycetes growing at 60° C. This type of hay was produced experimentally by baling at 35% moisture content, when the temperature rose to 60° C, the quantity of streptomycete spores increased greatly and farmer's lung antigens reached a maximum, all within 5 days. The two streptomycetes, *Thermopolyspora polyspora* (? *Micropolyspora* sp.) and to a smaller extent *Micromonospora* (*Thermoactinomyces*) *vulgaris*, were shown to be potent sources of the antigens. Thermophilic organisms including *T. polyspora* can also develop in unsealed tower silos used for storing moist, unripe barley grain. As the streptomycete spores are small (1 μ diameter), simple gauze masks do not give protection, and efficient dust respirators must be used.

6.21 HILL, J. M. & MANN, P. J. G. (1966) The oxidation of Schiff bases of pyridoxal and pyridoxal phosphate with amino acids by manganous ions and peroxidase. *Biochem. J.* **99**, 454–468.

1. Oxygen was taken up rapidly when pyridoxal or pyridoxal phosphate was added to mixtures of pea-seedling extracts and Mn^{2+} ions. 2. The increases in total oxygen uptake were proportional to the pyridoxal or pyridoxal phosphate added, and were accompanied by the disappearance of these compounds. 3. In addition to Mn^{2+} ions, the reactions depended on two factors in the extracts, a thermolabile one in the non-diffusible material and a thermostable one in the diffusate; these factors could be replaced in the reactions by horse-radish peroxidase (donor-hydrogen peroxide oxidoreductase, EC 1.11.1.7) and amino acids respectively. 4. When pyridoxal phosphate was added to mixtures of amino acids and Mn^{2+} ions, oxygen uptake was rapid after a lag period of 30–90 minutes; the lag period was shortened to a few minutes by peroxidase, particularly in the presence of traces of *p*-cresol, or by light. 5. When pyridoxal replaced pyridoxal phosphate, relatively high concentrations were required and peroxidase had only a small activating effect. 6. Pyridoxal or pyridoxal phosphate disappeared during the reactions and carbon dioxide and ammonia were formed. 7. With phenylalanine as the amino acid present, benzaldehyde was identified as a reaction product. 8. It is suggested that the reactions are oxidations of the Schiff bases formed between pyridoxal or pyridoxal phosphate and amino acids, mediated by a manganese oxidation–reduction cycle, and resulting in oxidative decarboxylation and deamination of the amino acids.

Plant Pathology Department

GENERAL PAPERS

7.1 BAWDEN, F. C. (1966) Some reflexions on thirty years of research on plant viruses. (Presidential Address to Association of Applied Biologists.) *Ann. appl. Biol.* **58**, 1–11.

7.2 BAWDEN, F. C. (1966) John Bennet Lawes, Joseph Henry Gilbert—biographical sketches. *J. Nutr.* **90**, 1–12.

7.3 BAWDEN, F. C. (1966) Rothamsted Experimental Station. *Jl R. agric. Soc.* **127**, 54–61.

7.4 GREGORY, P. H. (1966) The fungus spore: what it is and what it does. In: *The fungus spore*, ed. M. F. Madelin. London: Butterworths, pp. 1–13.

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7.5 GREGORY, P. H. (1966) Dispersal. In: *The fungi: an advanced treatise*, ed. G. C. Ainsworth & A. S. Sussman. New York & London: Academic Press, Vol. 2, pp. 709–732.

7.6 HARRISON, B. D. (1966) Comments on the proposals and recommendations of the Provisional Committee for Nomenclature of Viruses. *Proc. 9th int. Congr. Microbiology*, pp. 453–459.

7.7 HIDE, G. A. & HIRST, J. M. (1966) Skin spot. *Seed Potato* **6**, 14–15.

7.8 HIRST, J. M. & (HURST, G. W.) (1967) Long-distance spore transport. In: *Airborne microbes*, ed. P. H. Gregory & J. L. Monteith. (*Symp. Soc. gen. Microbiol.* XVII), Cambridge University Press, pp. 307–344.

7.9 KASSANIS, B. (1967) Plant tissue culture. In: *Methods in virology*, ed. K. Maramorosch & H. Koprowski. New York & London: Academic Press.

7.10 KASSANIS, B. (1966) Properties and behaviour of satellite virus. In: *Viruses of plants*, ed. A. B. R. Beemster & J. Dijkstra (*Proc. int. Conf. Plant Viruses*, Wageningen 1965). Amsterdam: North Holland Publishing Company, pp. 177–187.

7.11 KLECZKOWSKI, A. (1966) Serological properties of viruses and their fragments. In: *Viruses of plants*, ed. A. B. R. Beemster & J. Dijkstra (*Proc. int. Conf. Plant Viruses*, Wageningen 1965). Amsterdam: North Holland Publishing Company, pp. 196–204.

7.12 SALT, G. A. (1965) Pathology experiments on Sitka spruce seedlings. *Rep. Forest Res., Lond.* for 1964, 89–95.

7.13 SALT, G. A. (1966) Pathology experiments on Sitka spruce seedlings. *Rep. Forest Res., Lond.* for 1965, 97–102.

7.14 WATSON, M. A. (1967) Epidemiology of aphid-transmitted plant-virus diseases. *Out. Agric.* **5**, 155–166.

RESEARCH PAPERS

7.15 (CALVERT, E. L.) & HARRISON, B. D. (1966) Potato mop-top, a soil-borne virus. *Pl. Path.* **15**, 134–139.

Potato mop-top (PMTV), a previously undescribed soil-borne virus, was found in 24 potato varieties, in plants which showed haulm symptoms ranging from yellow or pale green marking on the leaves to stunted stems bearing crowded leaves (mop-top), but was not found in symptomless plants. In the first year of infection tubers of some varieties showed raised necrotic rings on their surface with underlying arcs of corky tissue, in some ways resembling spraing caused by tobacco rattle virus (TRV). However, the two viruses had different effects on some varieties and produced different symptoms in *Chenopodium amaranticolor*. PMTV was the more readily transmitted from mother to progeny tubers and, unlike TRV, its spread in soil was not confined to fields infested with stubby root nematodes (*Trichodorus* spp.). PMTV is sap-transmissible, though not readily, to *C. amaranticolor*, the most useful indicator species, and it infected tobacco seedlings grown in previously air-dried soil from fields where potatoes became infected. In a few of the potato stocks examined 80% of the tubers were infected, but in most stocks the incidence was small.

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7.16 FESTENSTEIN, G. N., GREGORY, P. H., LACEY, J. & SKINNER, F. A. (1966) The microbiology of mouldy hay. *Proc. R. Soc. Med.* **59**, 1007–1008. (For summary see No. 6.20)

7.17 (FROST, R. R.), HARRISON, B. D. & WOODS, R. D. (1966) Apparent symbiotic interaction between particles of tobacco rattle virus. *J. gen. Virology*. **1**, 57–69.

The predominant lengths of tubular particles produced by the CAM isolate of tobacco rattle virus (50 and 195 mμ long) and of the PRN isolate (65–80 and 190 mμ long) were separated by density-gradient centrifugation. On their own, short particles of each isolate neither caused lesions in *Chenopodium amaranticolor* leaves nor multiplied detectably. Long particles of either isolate caused lesions that contained virus nucleic acid, but virus particles were not found in extracts of the lesions; when the lesions were stored 3 days at −15° C and thawed their extracts had little or no infectivity. Mixing short with long particles of the same isolate did not affect the number of lesions produced by the long particles, but caused a proportion of these lesions to contain tubular virus particles of both lengths and infective material resistant to freezing and thawing. This proportion increased from zero to unity with increasing concentration of short particles in the inoculum; it also increased with increasing susceptibility to infection of the plants used as the *source* of the lesions, but seemed unaffected by the concentration of long particles in the inoculum. The lesions containing stable virus particles of isolate CAM could be distinguished by their smaller necrotic centres. Ultra-violet irradiation of short particles abolished their ability to interact with long ones, but removing the protein from both long and short particles by phenol did not. No interaction was detected between particles of the two different isolates, which are distantly related serologically, or between their nucleic acids. Each isolate of tobacco rattle virus seems to be a system of two or more pieces of infective nucleic acid interacting specifically in a symbiotic manner.

7.18 GIBBS, A. J. (1966) A possible correlation between sugar beet yellows incidence and sunspot activity. *Pl. Path.* **15**, 150–152.

Records kept since 1946 of the incidence of virus yellows in British sugar-beet crops show that the incidence of the disease in each of the months July, August and September is closely correlated with its incidence in the previous month. Incidence in June is independent of the incidence in the previous year, but seems to be correlated with sunspot activity during the previous summer; a possible mechanism for the relationship is suggested.

7.19 GIBBS, A. J., HARRISON, B. D., (WATSON, D. H. & WILDY, P.) (1966) What's in a virus name? *Nature, Lond.* **209**, 450–454.

Ideally, the name of a virus should be: (1) simple, easily understood and usable by people speaking different languages; (2) indicative of the properties of the virus named; (3) unchanging. The main difficulty is to devise names that are unchanging, or rarely change, and yet indicate what is known of the properties of the virus named, when this is continually increased by research. The reasons why neither vernacular names nor latinised binomials can adequately meet these requirements are discussed. Virus nomenclature will be most useful if based on a classification of viruses that takes into account all known properties of the viruses, without giving special weight to any. Also any system adopted now should not prejudice future developments.

The solution suggested is a system in which the current vernacular name

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continues to be used accompanied by a cryptogram indicating present knowledge of several of the properties of the virus, and its affinities. The cryptogram part would appear only once in a scientific paper, to specify the virus, and is not intended to be spoken. As a basis for discussion, a cryptogram using four terms is described. The symbols used are intended to be suggestive of the characters they represent. For example, *tobacco ringspot virus* $R/1:2/35:S/S:S/N:$ *NEPO-group* means that the nucleic acid in the infective particle contains ribose, is single stranded, has a weight of 2 million daltons and constitutes 35% of the particle weight; the outline of the particle is essentially spherical, as is the shape of the nucleocapsid; the virus infects seed plants, is transmitted by nematodes and is considered by specialists to be one of the so-called NEPO-group of viruses. An asterisk would be inserted where there is no information on the property; for example, potato leaf roll virus would have the cryptogram $*/*:*/*:*/*:S/A$. Any such new names for viruses should be subject to approval by an international body.

7.20 GIBBS, A. J., HARRISON, B. D. & WOODS, R. D. (1966) Purification of pea enation mosaic virus. *Virology* **29**, 348–351.

Pea enation mosaic virus was purified from leaves of bean (*Vicia faba* L.) by extracting the virus in phosphate buffer containing ethylenediaminetetra-acetate plus chloroform, and subjecting the aqueous extract to differential high- and low-speed centrifugation, followed by centrifugation in sucrose density-gradients. The virus preparations contained two components with sedimentation coefficients of about 97 S and 116 S. Both were particles about 30 mμ in diameter, but distinguishable in the electron microscope by their general appearance. Purified preparations also contained two specific antigens, which may correspond to the two components distinguished in the analytical ultracentrifuge and electron microscope. Bean plants infected from the purified preparations developed symptoms typical of pea enation mosaic, and the virus was transmitted in the persistent manner by aphids from such plants. On its own the 97 S component caused minute local lesions in *Chenopodium amaranticolor* leaves. Preparations of the Rothamsted culture of pea enation mosaic virus reacted with antiserum prepared against an American culture of the virus.

7.21 GIBBS, A. J., HECHT-POINAR, E., WOODS, R. D. & (MCKEE, R. K.) (1966) Some properties of three related viruses: Andean potato latent, dulcamara mottle and Onosis yellow mosaic. *J. gen. Microbiol.* **44**, 177–193.

Three similar and apparently previously unrecorded viruses were studied and found to be most like viruses of the turnip yellow mosaic group. Andean potato latent virus (APLV) was obtained from primitive cultivated potatoes collected in the high tropical Andes, dulcamara mottle virus (DMV) from *Solanum dulcamara* L. growing near Rothamsted and Ononis yellow mosaic virus from *Ononis repens* L. growing in many parts of England. All three viruses are readily transmitted by sap inoculation; APLV and DMV are transmitted through the seed of infected plants; DMV is transmitted by the flea beetle *Psylloides affinis* Paykull. Plants infected by one of the viruses are not protected against infection by the others.

Purified preparations of these viruses have many common properties. Each virus has isometric particles 25–30 mμ in diameter, indistinguishable in appearance from one another and from the particles of turnip yellow mosaic virus. Preparations of each contain mainly two types of particles with sedimentation coefficients of about 115 S and 55 S, corresponding to infective nucleoprotein particles and non-infective "empty" particles respectively. Each virus contains nucleic acid with a molar base composition of about G 16%, A 22%, C 33%,

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U 29%. The three viruses are serologically related; antisera titres are 8–128 times greater with homologous than with the heterologous viruses. No serological relationship was found between these viruses and turnip yellow mosaic, wild cucumber mosaic, cocoa yellow mosaic, squash mosaic and red clover mottle viruses.

Plants infected with APLV or DMV produced fewer nucleoprotein particles and more "empty" protein particles when sprayed with solutions of 2-thiouracil or 6-azauracil than when sprayed with water.

7.22 GIBBS, A. J., VARMA, A. & WOODS, R. D. (1966) Viruses occurring in white clover (*Trifolium repens* L.) from permanent pastures in Britain. *Ann. appl. Biol.* **58**, 231–240.

Twenty-five white clover plants were collected along a transect in each of 26 old permanent pastures in Britain and tested for sap-transmissible viruses. Viruses were identified by the symptoms they caused, by electron microscopy and by serological tests. Of the 683 plants tested, 23% were infected. In order of decreasing incidence the viruses found were: red clover vein mosaic (in 12% of all the plants tested, and in 16 of the fields); clover yellow vein (9% of plants, 18 fields); white clover mosaic (4% of plants, 11 fields); arabis mosaic (4% of plants, 8 fields); strawberry latent ringspot (1% of plants, 2 fields); and tomato black ring (0·1% of plants, 1 field). The three most common viruses occurred in all parts of Britain, and were most prevalent in fields where white clover was most abundant; white clover mosaic seemed more prevalent in fields that were both cut and grazed than in those only grazed. Arabis mosaic virus was obtained only from plants in the west and north of Britain.

7.23 HARRISON, B. D. (1966) Further studies on a British form of pea early browning virus. *Ann. appl. Biol.* **57**, 121–129.

An isolate of pea early-browning virus from Britain (PEBV (B)) has tubular particles, most of which are either about 103 or 212 mμ long with sedimentation coefficients of 210 and 286 S respectively. Both types show cross-banding at intervals of 2·5 mμ. Virus preparations containing only the shorter particles were not infective.

PEBV (B) was transmitted to pea seedlings by both adult and juvenile *Trichodorus primitivus* (de Man) (Nematoda) and persisted for 32 days in *T. primitivus* kept without plants. In two experiments *T. primitivus* failed to transmit a Dutch isolate (PEBV (D)), which is distantly related serologically to PEBV (B). PEBV (B) was transmitted by nematodes to cucumber roots more readily in soil at 20° than at 24° C, and more readily at 24° than at 29° C.

When transmitted by inoculation of sap, PEBV (B) and PEBV (D) caused similar symptoms in some pea varieties but differed in virulence towards others. Thirty-one varieties resistant to natural infection with PEBV in the Netherlands were susceptible to PEBV (B) when manually inoculated with sap or when grown in naturally infested soil from one site; 26 of these varieties did not become infected in soil from a second site, in which several other varieties that are susceptible in the Netherlands were infected. Varieties should therefore be tested for resistance by growing them on many infested fields. All but one of the pea varieties resistant to PEBV in the Netherlands became infected with the English form of tomato black ring virus when grown in soil containing infective *Longidorus attenuatus* Hooper.

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7.24 HARRISON, B. D. & (KLUG, A.) (1966) Relation between length and sedimentation coefficient for particles of tobacco rattle viruses. *Virology* **30**, 738–740.

Each isolate of tobacco rattle virus produces particles of 185–197 mμ long, together with one or more kinds of shorter particles with a length or lengths characteristic of the isolate. This series of essentially cylindrical particles, having the same diameter but different known lengths (l) and sedimentation coefficients (s), was used to examine the relation between l and s. When the frictional ratio of the particles was taken to equal that of prolate ellipsoids having the same volume and length as the particles seen in the electron microscope, $s \times$ frictional ratio was directly proportional to $l^{\frac{2}{3}}$. Using this relation in conjunction with other measurements, weights of about 48×10^6 and 50×10^6 daltons were calculated for the infective particles of serotype I (188 mμ long) and of serotypes II and III (196 mμ long). Assuming that the particles contain only one kind of protein sub-unit, this was calculated to have a molecular weight of $2{\cdot}4 \times 10^4$.

7.25 HARRISON, B. D. & WOODS, R. D. (1966) Serotypes and particle dimensions of tobacco rattle viruses from Europe and America. *Virology* **28**, 610–620.

Five tobacco rattle viruses from Britain and one from the Netherlands were closely related serologically (serotype I), but were only distantly related to one from Brazil (serotype III), which in turn was only distantly related to two from the United States (serotype II). No serological relationship was detected between three tobacco rattle viruses from the United States and one of serotype I, but other workers have found distant relationships between tobacco rattle viruses from the United States and the Netherlands. All ten tobacco rattle viruses examined have straight tubular particles of two or more different lengths, and these lengths are characteristic of the virus isolate. Only the longest particles are infective; these have modal lengths of 188 mμ (serotype I), 195 mμ (serotype II) and 197 mμ (serotype III), and sedimentation coefficients of about 305 S at infinite dilution. The viruses fall into six groups (A–F) on the basis of the modal lengths of their shorter particles, which range from 43 to 114 mμ, but these groups do not correspond to the serotypes. Eight of the viruses retained their characteristic particle lengths unchanged after repeated subculture in the glasshouse, but two, which initially had particle lengths characteristic of group F, changed to lengths of other groups. The main components shown in the diagrams of particle-length distribution were also identified in the analytical ultracentrifuge, showing that they are not artifacts of electron microscopy. The short particles of tobacco rattle viruses seem likely to be specific products of virus-infected cells rather than precursors or fragments of the long particles.

The ratio of sedimentation coefficient to particle length is larger for tobacco rattle viruses than for pea early-browning virus, and the particles of tobacco rattle viruses appear about 6% wider in the electron microscope. All these viruses are alike in that the two ends of individual particles differ from one another in shape.

7.26 KASSANIS, B. & SUTIC, D. (1965) Some results of recent investigations on šarka (plum pox) virus disease. *Zastita bilja, Beograd*, No. 85–88, 335–340.

Three virus isolates were transmitted mechanically from plum and apricot with šarka disease to *Nicotiana clevelandii*. They produced severe necrotic ring spot and systemic mottle in *N. clevelandii* and necrotic local lesions in *Chenopodium foetidum*, had a thermal inactivation end-point between 52° and 55° C

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and longevity *in vitro* between 30 and 35 hours. The virus particles were long flexuous rods, with the most frequent length 725 mμ. The virus was transmitted by *Myzus persicae* from plum and *N. clevelandii* to seedlings of *N. clevelandii*.

Return inoculations from *N. clevelandii* to young seedlings of *Prunus cerasifera* (Myrabolan) showed that the isolates caused šarka.

7.27 LACEY, J. (1966) The distribution of healthy and blighted tubers in potato ridges. *Eur. Potato J.* **9**, 86–98.

Maps were made of the distributions of tubers of plants of 15 potato varieties growing in the field. Although distribution was mainly a varietal characteristic, there was some evidence that it could be affected by soil type and seasonal differences. Varieties with short stolons (e.g. *Ulster Tarn*) not only had tubers tightly clustered but tended to have many near the soil surface. As the proportions of long stolons increased, so the clustering diminished and tubers were usually deep and widely spread in varieties with mostly long stolons (e.g. *Arran Viking*). The proportion of tubers infected by blight decreased with increasing depth. In 1960, when tuber infection was common, more than half the tubers in the top 5·1 cm of soil were infected, but only an occasional one was blighted 15·2 cm below the surface.

7.28 LAPWOOD, D. H. (1966) The effects of soil moisture at the time potato tubers are forming on the incidence of common scab (*Streptomyces scabies*). *Ann. appl. Biol.* **58**, 447–456.

Two complementary field experiments at Rothamsted in 1965 with the potato variety Majestic, related the incidence of common scab (*Streptomyces scabies*) to rainfall, soil moisture and time of tuber formation.

In plots where the soil was maintained at field capacity (less than 10 cm Hg moisture tension) by watering, tubers had little or no scab, which increased in amounts as plots were allowed to dry to 30 cm, 50 cm or more Hg moisture tension during late June.

The time tubers formed was varied by planting sprouted (chitted) and non-sprouted seed tubers, and tuber development and scab incidence were observed on sample plants lifted at frequent intervals from unwatered plots. Scab lesions were first seen on 12 July, when the distribution of lesions on the surface of tubers varied between different-sized tubers both within and between the different seed tuber treatments. These differences were correlated with estimates of tuber size on 28 June, the beginning of the first dry period. Tubers 1·0 cm or more in diameter on 28 June had few or no lesions at the stolon attachment (heel) end of tubers on 12 July, whereas tubers smaller than this on 28 June had many lesions in this region on 12 July. The larger the tuber was on 28 June, the greater was the area free from scab lesions on 12 July.

7.29 LAPWOOD, D. H. & (MCKEE, R. K.) (1966) Dose-response relationships for infection of potato leaves by zoospores of *Phytophthora infestans*. *Trans. Br. mycol. Soc.* **49**, 679–686.

The relationship was studied between the number of zoospores (dose) of *P. infestans* applied as inoculum and the relative infection (response) of the upper surface of leaves of nine varieties differing in field susceptibility to potato blight. The ED 50 values (the number of spores required for 50% infection) calculated from probit analysis for varieties with little (Bintje, King Edward, Up-to-Date) or intermediate (Arran Viking, Majestic, Ulster Supreme) field resistance ranged from 6 to 15 spores/drop with no clear differences between the groups, whereas

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the ED 50 of resistant varieties (Libertas, Pimpernel, Zeeburger) ranged from 23 to 46 spores.

Differences in ED 50 values between varieties were smaller when the lower leaf surface was inoculated and, with few exceptions, susceptibility to infection was greater than on the upper surface.

As the dose decreased, the average generation time (time to sporulate) increased with all varieties, and with the dose constant, generation times were longer with resistant than susceptible varieties.

7.30 (MacGarvie, Q. D.) & Hide, G. A. (1966) *Verticillium* species from potato seed stocks in Britain in 1965. *Pl. Path.* **15**, 72–75.

The incidence of *Verticillium* species in seed potatoes was estimated in 1965 on samples from 225 seed stocks. *Verticillium* species were isolated from 79% of the stocks, but *V. alboatrum* and *V. dahliae* were not found. *V. tricorpus*, *V. nubilum* and *V. nigrescens* occurred in 72·5, 10·2 and 8·5% of the stocks respectively and were most often isolated from sprouts. These three species were also found in growing plants.

7.31 Okusanya, B. A. M. & Watson, M. A. (1966) Host range and some properties of groundnut rosette virus. *Ann. appl. Biol.* **58**, 377–387.

Two isolates of groundnut rosette virus from East Africa ($GRVE_1$ and $GRVE_2$) and from West Africa ($GRVW_1$ and $GRVW_2$) were transmitted by *Aphis craccivora* obtained from West Africa. A third isolate from West Africa ($GRVW_3$) was not transmitted by *A. craccivora* from three widely separated sources. $GRVW_1$, $GRVW_2$ and $GRVW_3$ caused leaf-symptoms in ground nut of a mosaic pattern in light and dark green. $GRVE_1$ and $GRVE_2$ caused chlorosis or chlorosis and leaf-distortion in addition to mosaic. Groundnut plants with $GRVW_1$ could not be infected by aphids with $GRVE_1$, and $GRVE_1$ protected plants against $GRVW_1$, which suggests that they are strains of the same virus.

All isolates were transmissible manually from groundnut to groundnut (*Arachis hypogea*), *Trifolium incarnatum* and *T. repens*, and caused systemic infection. Inoculated *Nicotiana clevelandii* and *N. rustica* developed symptoms, but virus could not be recovered from them. *Chenopodium amaranticolor*, *C. hybridum* and *C. quinoa* produced local lesions. Virus could be acquired by aphids from groundnut or *T. repens* infected by aphids, but not from those infected by manual inoculation. Virus could not be recovered from *T. incarnatum* manually or by aphids, but was transmitted by cleft-grafting from clover to groundnut.

Saps extracted in borax buffer plus zinc sulphate at pH 9 from plants infected with $CRVW_1$ and $CRVE_1$ remained infective at 18° C for 1 week, and at −20° C for up to 4 weeks. Buffered saps lost infectivity when heated above 50° C for 10 minutes; most were still infective when diluted $\frac{1}{10}$ and some at $\frac{1}{100}$.

Electron micrographs of partially purified preparations contained spherical particles 25–28 mμ in diameter. There were usually only about five per microscope field and they resembled those of some other viruses.

7.32 Serjeant, E. P. (1967) Some properties of cocksfoot mottle virus. *Ann. appl. Biol.* **59**, 31–38.

Cocksfoot mottle virus (CFMV) was transmitted by manual inoculation of sap to cocksfoot (*Dactylis glomerata* L.), wheat, oats and barley, but not to 19 other monocotyledonous or 13 dicotyledonous plant species. The virus was also transmitted by cereal leaf beetles (*Lema melanopa* L.). Adult beetles transmitted more frequently than larvae, and remained infective for up to 2 weeks after

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they had fed on infected plants. Seed from infected cocksfoot and oat plants produced virus-free seedlings.

The infectivity of sap was lost during 10 minutes at 65° C, and 2 weeks at 20° C, but survived many months at −15° C.

Purified virus preparations, made by various methods, contained numerous nearly spherical particles, about 30 mμ in diameter, which migrated as one component in a centrifugal (sedimentation coefficient = 118 S) or electrophoretic field. The ultra-violet absorption spectrum, and the phosphorus and nitrogen contents of the virus preparations, were typical of a nucleoprotein containing about 25% nucleic acid.

Serological tests failed to show any relationship between CFMV and 11 other viruses with particles of similar shape and size.

7.33 SERJEANT, E. P. (1967) The transmission of European wheat striate mosaic virus by *Javesella pellucida* (Fabr.) injected with extracts of plants and plant-hoppers. *Ann. appl. Biol.* **59**, 39–48.

Virus-free individuals of the plant-hopper *Javesella pellucida* (Fabr.) infected plants with European wheat striate mosaic virus (EWSMV) after being injected at 5° C with extracts of either plants or hoppers, but extracts of hoppers provided a better inoculum. Hoppers did not infect plants until at least 8 days at 20–25° C after they were injected, and nymphs fed on infected plants similarly required 8 days before they gave infective extracts. Few hoppers survived more than a week after being injected with crude extracts of hoppers or with material sedimented from the extracts by centrifuging at 8,000 *g*, but 60–70% survived injection with purer virus preparations. Injection of the virus seemed harmless, because as many hoppers survived CO_2 anaesthesis + injection, whether or not they later infected plants, as survived anaesthesis without injection. Attempts to determine the properties of the virus *in vitro* gave inconsistent results, but virus from hoppers was still infective after 10 minutes at 30° C, 36 hours at 5° C, precipitation at pH 4·0, storage for several months at −15° C, or at a dilution equivalent to 0·0014 g hopper/ml. The best extraction medium contained 0·2*M*-Na_2HPO_4 + ascorbic acid + 0·01*M*-DIECA at pH 7·0–7·3.

In sucrose density-gradients EWSMV sedimented slower than tobacco mosaic virus. No specific particle with which infectivity could be correlated was seen by electron microscopy.

7.34 VARMA, P. & GIBBS, A. J. (1967) Preliminary studies on sap-transmissible viruses of red clover (*Trifolium pratense* L.) in England and Wales. *Ann. appl. Biol.* **59**, 23–30.

Red clover plants, collected from nine widely separated permanent pastures in England and Wales, were tested for sap-transmissible viruses. Viruses were identified by the symptoms they caused in test plants, by electron microscopy and by serological tests. Of the 265 plants tested, 14% were infected. Only pea mosaic virus was common and widespread; it was found in 8% of the plants, and in seven of the fields. Other viruses isolated were arabis mosaic, bean yellow mosaic, red clover mottle and red clover vein mosaic; only red clover mottle virus produced diagnostic symptoms in red clover. Viruses were not detected in seedlings grown from seed from 89 commercial seed crops. Attempts to transmit red clover mottle virus by the Collembola *Sminthurus viridis* L., which is common on red clover, failed.

7.35 WATSON, M. A. (1966) The relation of annual incidence of beet yellowing viruses in sugar beet to variations in weather. *Pl. Path.* **15**, 145–149.

The incidence of aphid-borne yellowing viruses in sugar-beet root crops can be

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related to the number of days in January, February and March when temperatures fell below 0° C, and to the mean weekly temperatures in April. Values calculated from partial regressions of angular transformations of percentage of plants infected at the end of August on log number of freezing days and April temperatures fitted observed values for virus incidence closely between 1950 and 1965, but not between 1940 and 1949. April temperatures influenced virus incidence more during the earlier period, partly because they were warmer and aphids were more active during late spring, but also because sugar-beet seed crops were then often extensively infected and aphid-movements were more effective in transferring viruses to nearby root crops.

The amount of virus in seed crops was independent of winter and spring weather, and so regressions on these factors accounted for much less variance in virus incidence than they did from 1950 onwards, when yellows was largely controlled in the seed crops.

Nematology Department

General Papers

8.1 Jones, F. G. W. (1966) The population dynamics and population genetics of the potato cyst-nematode, *Heterodera rostochiensis* Woll. *Rep. Rothamsted Exp. Stn* for 1965, 301–316.

8.2 Webster, J. M. (1967) The effect of 2,4-D on plant parasitic nematodes in culture and *in vivo*. *Nematologica*. (In the press.)

8.3 Webster, J. M. (1966) The host–parasite relationship; method of resistance to plant-parasitic nematodes. *Parasitology* **56**, 9 P.

Research Papers

8.4 Clark, S. A. (1967) The development and life history of the false root-knot nematode, *Nacobbus serendipiticus*. *Nematologica* **13**, 91–101.

The development from egg to adult was studied on tomato. There are four larval stages, the first moult taking place in the egg. Sex can be distinguished in the late third stage, the female gonad being longer and more posterior than the male. Damage to the host roots caused by the larvae feeding and invading is followed by necrosis of cortical cells. Galls occur only in association with adult females; they contain a spindle-shaped mass of small cells in which starch grains are found. Of 25 plant species tested for susceptibility, mature females were recovered from eight. The nematodes can survive the winter in England, but are probably not indigenous.

8.5 Clarke, A. J. & Shepherd, A. M. (1966) Picrolonic acid as a hatching agent for the potato cyst nematode, *Heterodera rostochiensis* Woll. *Nature, Lond.* **211**, 546.

Picrolonic acid (4-nitro-3-methyl-1-p-nitrophenylpyrazolone), at concentrations of 0·4–4 mM, was the only compound from more than 400 tested that hatched eggs of *H. rostochiensis* as well as did potato root diffusate and anhydrotetronic acid. Like that acid, it has two linked rings and an acidic, enolic group as part of a potentially tautomeric system of two polarisable atoms separated by an extended chain.

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8.6 CLARKE, A. J. & SHEPHERD, A. M. (1966) Inorganic ions and the hatching of *Heterodera* spp. *Ann. appl. Biol.* **58**, 497–508.

Zn^{2+} hatched many eggs of seven species and some of *H. goettingiana*, but inhibited hatch of *H. avenae* to below that in water. Zinc salts are the first recorded very active hatching stimulants for *H. glycines in vitro*. Many other metal ions stimulated hatching of *H. schachtii* eggs to varying extents; these also hatched some but not all of the other species. Vanadate ions were especially effective with *H. rostochiensis*, more so than Zn^{2+}. No ion increased the hatch of *H. avenae* to above that in water. The most active ions were not those most abundant in soil.

8.7 CLARKE, A. J. & SHEPHERD, A. M. (1967) Flavianic acid as a hatching agent for the cabbage cyst nematode, *Heterodera cruciferae* Franklin, and other cyst nematodes. *Nature, Lond.* **213**, 419–420.

Flavianic acid (2,4-dinitro-1-naphthol-7-sulphonic acid), at 0·6 mM concentration, hatched more eggs of *Heterodera cruciferae* than did cabbage root diffusate at optimum strength. It also hatched *H. glycines*, *H. schachtii*, *H. tabacum* and *H. trifolii* but not *H. carotae* or *H. rostochiensis*.

8.8 CORBETT, D. C. M. (1966) Central African nematodes. III *Anguina hyparrheniae* n. sp. associated with witches' broom of *Hyparrhenia* spp. *Nematologica* **12**, 280–286.

Anguina hyparrheniae is a new species associated with a "witches' broom" condition of the inflorescences of several species of the tropical grass, *Hyparrhenia*. The nematode most closely resembles *A. spermophaga* Steiner, but differs from it in the size and shape of the terminal process of the tail of both sexes and in having a smaller female gonad with no flexures and a larger post-uterine sac. The male also has a shorter tail than that of *A. spermophaga*.

8.9 DONCASTER, C. C. (1966) Nematode feeding mechanisms. 2. Observations on *Ditylenchus destructor* and *D. myceliophagus* feeding on *Botrytis cinerea*. *Nematologica* **12**, 417–427.

D. destructor and *D. myceliophagus* behaved similarly when feeding on *Botrytis*, but differed in detail from *D. destructor* feeding on other fungi. Body contractions controlled turgor pressure, but the region where pressure increase was initiated decided different bodily functions: anterior contraction caused gland secretions to be injected into the host, and rhythmical posterior contractions caused intestinal movements that mixed the contents. Feeds last from ¾ hr to 2¾ hours and were nearly equally divided into injection and ingestion phases. Ingestion was by parts of the posterior of the pharynx pulsating with occasional assistance from the pump in the median bulb, but this eventually obstructed further feeding by locally disrupting the contents of the host. Several cells at the feeding site died after being fed on.

8.10 DONCASTER, C. C. (1967) Additional notes on setting up moisture-controlled observation chambers. *Nematologica* **12**, 645.

Suggestions are made for modifying the pattern and the method of setting up moisture-controlled observation chambers.

8.11 DONCASTER, C. C., EDWARDS, B. S. & SHEPHERD, A. M. (1967) A labour-saving method of making Fenwick multi-chamber counting slides. *Nematologica* **12**, 644–645.

Details are given of commercially available components for Fenwick multi-chamber counting slides, two types of press in which the components can be bonded and of constructional practice.

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8.12 GREEN, C. D. (1966) Orientation of male *Heterodera rostochiensis* Woll. and *H. schachtii* Schm. to their females. *Ann. appl. Biol.* **58**, 327–334.

A chemical attractive to their males is emitted by females of *H. rostochiensis* and *H. schachtii*. The attraction is evident in agar plates when the females have been killed or removed from the agar and, on 3-mm-thick agar, it takes more than 15 minutes at 20° C to diffuse and be perceptible to males 5 mm from the females. The perception is gustatory and seems to elicit klinokinetic aggregation behaviour and klinotactic orientation. The males stop when stimulation decreases and then either reverse and turn or swing and turn. Fatigue of the receptors, leading to loss of acuity of perception, occurs with more concentrated attractant, which lessens the frequency of turning, but increases its intensity so the approach to the female is less well orientated. Females of *H. schachtii* secreted a less labile or more concentrated attractant than females of *H. rostochiensis*, and their males were frequently less well orientated.

8.13 GREEN, C. D. (1967) The attraction of male cyst-nematodes by their females. *Nematologica* **13**, 172–173.

Mature white females of *H. schachtii* were embedded in agar exposed in an enclosed layer of air 1 mm thick, 20 mm × 20 mm. Some females were so arranged that there was no contact between them and a lower agar surface on which males were placed; other females bridged the gap between the surfaces. In the first group males could be attracted only by a volatile compound in the air, whereas in the second a compound dissolved in water could diffuse to the males. Males reacted only when there was an aqueous link to the females and, in soil, presumably move along gradients of attractants in the water films around soil particles.

8.14 GREEN, C. D. (1967) Preparation of nematodes for examination under the Stereoscan Electron Microscope and examples of photomicrographs obtained. *Nematologica* **13**. (In the press.)

The Cambridge "Stereoscan" electron microscope allows nematode cuticle to be seen in greater detail than heretofore, but does not show underlying structures. Resolution is better than 200 Å. The specimens are examined in a vacuum, so all volatile liquids must be removed. Care is necessary to prevent cuticular distortion: fixation in TAF followed by impregnation in glycerol or polyethylene glycol (400), to replace all water, provided the best specimens. In glycerol the nematodes were flaccid and spicules and stylets might be withdrawn, but in polyethylene glycol the nematodes became rigid. Specimens were stuck to a small microscopic cover glass with "Durofix", nail varnish or "Glyceel", and examined dry under a light microscope before the glass was attached to the "Stereoscan" mounting block with the nematodes uppermost. The specimens were then coated *in vacuo* with a gold–palladium mixture to make the surface electrically conducting before they were placed in the specimen chamber of the "Stereoscan" microscope. The most common artefact was crinkling of the cuticle from contraction of underlying tissue.

8.15 GREEN, C. D. & PARROTT, D. M. (1967) A re-appraisal of the extraction of *Heterodera* cysts from large volumes of soil. *Nematologica* **12**, 601–609.

The labour of extracting cysts from large volumes of soil was lessened by redesign of the flotation apparatus and making some of the process automatic. Fine soil, without particles larger than 0·6 cm, was fed into a hopper in the room below. A vibratory chute supplied soil continuously to a tank of water in which

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the particles mixed with the water and then sedimented. The cysts overflowed on to sieves, coarse debris was removed on a 813-μ sieve and the cysts collected on a 230-μ sieve below. A funnel fitted below the water level in the tank enabled sediment to be removed continuously with a peristaltic pump. The extraction of cysts by this method was equal to, or better than, by the Fenwick can method.

8.16 GREEN, C. D. & PLUMB, S. C. (1967) The effect of ultra-violet radiation on invasion, survival and fertility of *Heterodera rostochiensis* Woll. *Nematologica* **13**. (In the press.)

Suspensions of second-stage (newly hatched) larvae of *Heterodera rostochiensis* were exposed to ultra-violet radiation at doses from 16 to 16,000 μW min/cm² and of *H. schachtii* at doses from 500 to 15,000 μW min/cm². Both species were immobilised after 10,000 μW min/cm². The number of *H. rostochiensis* larvae invading and establishing in potatoes decreased to one-tenth after 500 μW min/cm², and the numbers of males and females that developed decreased proportionately. Even after 500 μW min/cm² both the males and the females were fertile.

8.17 HEATHCOTE, G. D., GREET, D. N. & WHITEHEAD, A. G. (1966) Effect of fumigating sandy soil on the growth of sugar beet. *Pl. Path.* **15**, 120–124.

Beet on untreated land containing parasitic nematodes at Hopton, Norfolk, was stunted and deficient in nutrients. Treatment with "D-D" and chloropicrin gave plants with normal foliage, greatly increased yields and lessened the incidence of soil-borne virus diseases. At Broom's Barn, where beet grew vigorously and yielded well on untreated soil, fumigation increased the number of seedlings that emerged but also gave many poor roots, as also happened at Hopton. Apparently the "D-D" damaged the beet. At Hopton only chloropicrin gave a yield of normal roots. Fumigating sandy soils prone to give plants with Docking disorder can prevent the disease, but cheaper methods are needed.

8.18 PRASAD, S. K. & WEBSTER, J. M. (1967) Effect of temperature on the rate of development of *Nacobbus serendipiticus* in excised tomato roots. *Nematologica* **13**, 85–90.

How temperature affects the rate of development of *Nacobbus serendipiticus* was studied in excised tomato roots in aseptic nutrient agar. Second-stage larvae entered the roots and small galls bearing lateral rootlets were associated with third-stage females. Males occurred in the galls and entangled in the egg sacs of females. The life-cycle from egg to egg was completed in 36 days at 25° C, and 43 days at 20° or 30° C. At 20° and 25° C some individual galls contained more than one female, but not at 30° C, where there were sometimes as many as four males per gall. The sex-ratio (males to females) was 2·33, 0·14, 1·00 and 7·33 at 15°, 20°, 25° and 30° C respectively.

8.19 PRASAD, S. K. & WEBSTER, J. M. (1967) The effect of amino acid antimetabolites on four nematode species and their host plants. *Nematologica* **13**. (In the press.)

8.20 SIDDIQI, M. R. & FRANKLIN, M. T. (1967) *Aphelenchoides goodeyi* n. sp. (Nematoda: Aphelenchoidea), a mycophagous nematode from South India. *Nematologica* **13**, 125–130.

A. goodeyi is distinguished by having a stellate mucro and short gonad. No males have been found, and the females are probably syngonic hermaphrodites.

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8.21 WEBSTER, J. M. (1967) Production of oat callus and its susceptibility to a plant parasitic nematode. *Nature, Lond.* **212**, 1472.

Actively growing callus tissue of the monocotyledons oat (*Avena sativa*) and onion (*Allium cepa*) was produced *in vitro*. Oat callus grew best on nutrient agar medium containing 2,4-dichlorophenoxyacetic acid (2,4-D) (5 mg/l), 3-indoleacetic acid (2 mg/l) and glucose (20 mg/l). Both tissues grew better in light than in dark. The Chrysanthemum nematode (*Aphelenchoides ritzemabosi*) was inoculated aseptically on to the callus and increased fifty-fold after 6 weeks. *A. ritzemabosi* is not recorded as a parasite of normal oat tissue.

8.22 WEBSTER, J. M. (1967) The significance of biological races of *Ditylenchus dipsaci* and their hybrids. *Ann. appl. Biol.* **59**, 77–83.

Pure cultures of six races of *Ditylenchus dipsaci* derived from single females, namely, lucerne race (LR), red clover race (RCR), white clover race (WCR), narcissus race (NR), tulip race (TR) and oat race (OR) were inoculated into eight plant species growing in pots. Onion was host to all six races, and tulip to all except RCR, whereas lucerne was susceptible only to LR and slightly to WCR. Hyacinth was not very susceptible to any race. The TR and OR were the most polyphagous. Severe symptoms were not necessarily associated with large nematode populations. Parthenogenesis did not occur. Ten fertile hybrids between races were produced, and the host range of five of these was tested. On average the hybrids multiplied less than their parent races, and their host ranges showed no relationship to those of their parent races. RCR and TR inoculated together into tulip produced significantly fewer nematodes than did TR alone and more than RCR alone. Mixed populations of races occur in nature which are probably a mixture of parental races, their hybrids and backcrosses. Repeated back-crossing of the hybrids with parental types and the slower multiplication of the hybrids is an explanation for the variation in host range of known races and the failure to record new races.

8.23 YUEN, P. H. (1966) The nematode fauna of the regenerated woodland and ungrazed grassland of Broadbalk Wilderness. *Nematologica* **12**, 195–214.

Of the 81 nematode species found in the soil of the regenerated woodland and the ungrazed grassland of Broadbalk Wilderness, 57 were common to both. The populations in the two sites contained different species of Tylenchida and different proportions of plant and bacterial feeders. The horizontal distribution of *Helicotylenchus* and *Rotylenchus* species differed in the two sites.

The population of *H. vulgaris* in the grassland had one peak in spring and another in summer. *R. pumilus* also had a spring peak earlier than *H. vulgaris*, but had no pronounced summer peak.

In the woodland and grassland, where vegetation cover was complete, nematodes were most abundant in the surface soil, and the density decreased with depth, except during August. In the Broadbalk wheat crop, where the soil was only partly covered, most nematodes occurred at 6·8 cm and few at 0·2 cm.

During November 1963, February, May and August 1964 most *R. pumilus* were at 0·2 cm in the grassland, but most *H. vulgaris* were at 4·8 cm in August and at 8·10 cm in February, with no pronounced population peak in May or November. The vertical distribution of neither species was related to amount of moisture or root in the soil; and neither species was observed to migrate vertically.

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Insecticides and Fungicides Department

General Papers

9.1 Lord, K. A. (1966) Causes of resistance in houseflies and some practical implications. *Proceedings of the 3rd British Insecticide and Fungicide Conference* 1965, 61–66.

9.2 McIntosh, A. H. (1966) Guarding the tubers. *Fmr Stk Breed.* No. 80, 3974, 46.

9.3 Needham, P. H. & Stevenson, J. H. (1966) Insecticides and beekeeping in England and Wales. *Bee Wld* **47**, 65–70.

9.4 Potter, C. (1966) Selectivity the solution. *Proc. R. ent. Soc. Lond.* **31**, 25–27.

Research Papers

9.5 Arnold, A. J. (1967) An electric insect barrier using a neon oscillator. *Pl. Path.* **16** (2). (In the press.)

An inexpensive mains or battery operated relaxation oscillator is described. The output of 25 V at 300 c/s is coupled to an electric barrier designed to confine insects within a given area. When wired in conjunction with a change-over relay and battery the barrier can remain energised should the mains fail. A wide range of insects were satisfactorily contained.

9.6 Arnold, A. J. (1967) Hand-operated micro-applicator to deliver drops of five sizes. *Lab. Pract.* **16**, 56–57.

A compact and robust hand-operated micro-applicator is described that rapidly selects and accurately delivers five sizes of drop ranging from 0·25 to 5 µl. To test the accuracy and consistency of the apparatus 10 individual drops of distilled water were weighed for each drop size. The coefficient of variation with the smallest drop of 0·25 µl was less than 2%.

9.7 Burt, P. E. (1966) Local removal of glass insulation from metal microelectrodes by air-abrasion. *J. scient. Instrum.* **43**, 664–665.

The removal of small areas of insulation from glass-insulated platinum–iridium microelectrodes with a jet of abrasive particles is described. The process can be controlled delicately and produces electrodes that minimise mechanical damage to tissues and shunting of the signal when extra-cellular potentials are recorded beneath the surface of conducting fluids.

9.8 Burt, P. E., Gregory, G. E. & Molloy, F. M. (1966) A histochemical and electrophysiological study of the action of diazoxon on cholinesterase activity and nerve conduction in ganglia of the cockroach *Periplaneta americana* L. *Ann. appl. Biol.* **58**, 341–354.

When sixth abdominal or metathoracic ganglia of the cockroach *Periplaneta americana* L. were irrigated continuously with diazoxon (*O*,*O*-diethyl-*O*-(2-isopropyl-6-methyl-4-pyrimidinyl)phosphate) solution *in situ* the log of the time required to block conduction in certain nerve pathways in the ganglia was directly proportional to the log of the concentration of diazoxon applied. Inhibition of cholinesterase began peripherally before function was affected, and had begun to affect the neuropile by the time conduction was first blocked. Longer exposure to diazoxon disrupted nerve function even more, especially in the sixth

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abdominal ganglion, and inhibited more cholinesterase, but much longer exposure was needed to inhibit nearly all the cholinesterase. Irrigation with saline, begun when block first occurred, failed to restore completely either nerve function or cholinesterase activity.

The cholinesterase activity of ganglia from cockroaches treated topically with an LD90 of diazoxon and examined at intervals after treatment decreased steadily to a level similar to that of ganglia treated directly with diazoxon until conduction was just blocked, but rarely became less, even in moribund insects. Nerve function in metathoracic ganglia became badly affected and remained so in all cockroaches that failed to recover, but sixth abdominal ganglia, though usually badly affected for a time, always recovered normal function, even in prostrate cockroaches. The condition of a poisoned insect, therefore, corresponded much more closely to the functional condition of the metathoracic ganglion than to that of the sixth abdominal ganglion.

Applying the insecticide close to a ganglion advanced the time of onset of symptoms but affected the final outcome very little.

The greatest concentration of diazoxon in the haemolymph in contact with the nervous systems of cockroaches treated topically with LD90's of diazoxon was calculated to be about $10^{-5}M$.

9.9 BURT, P. E., GREGORY, G. E. & MOLLOY, F. M. (1967) The activation of diazinon by ganglia of the cockroach *Periplaneta americana* L. and its action on nerve conduction and cholinesterase activity. *Ann. appl. Biol.* **59**, 1–11.

When sixth abdominal ganglia of the cockroach *Periplaneta americana* were irrigated continuously with diazinon solution *in situ* its effects on nerve conduction and cholinesterase activity closely resembled those of diazoxon; spontaneous activity and after-discharge increased until conduction was blocked, which happened while some cholinesterase was still uninhibited. The symptoms were only slightly relieved by irrigating ganglia with saline.

Though the LD50s of diazinon and diazoxon applied topically to adult male *P. americana* were similar ($2{\cdot}5 \pm 0{\cdot}33$ and $4{\cdot}5 \pm 0{\cdot}38$ μg per insect), diazoxon was about 300 times more active than diazinon against nerve function and cholinesterase activity in the sixth abdominal ganglion. This is probably because in the nerve preparations contact between the insecticide and the tissues surrounding the nerve cord, which in whole insects convert diazinon, a thionophosphate, into its phosphate analogue diazoxon, a more active anticholinesterase, was minimised. Indeed, considering previous *in vitro* comparisons of the anticholinesterase activities of several thionophosphates with those of their phosphate analogues, which showed the phosphates to be more active, the effect of diazinon on cholinesterase activity and nerve function in our experiments was unexpectedly great. By applying diazinon to nerve cords with SKF 525-A, a compound likely to prevent oxidation of diazinon to diazoxon, an attempt was made to decide whether diazinon directly affected nerve conduction, or whether the effect resulted either from its conversion to diazoxon within the nerve tissue or from impurities in the diazinon used. Results were inconclusive, for SKF 525-A (*p*-diethylaminoethyl diphenylpropylacetate hydrochloride) not only failed to prevent the inhibition of cholinesterase but interfered with the action of both diazinon and diazoxon on nerve conduction and itself affected nerve conduction when applied alone. The possibility that diazinon is itself a mild anticholinesterase was not excluded.

SKF 525-A applied to sixth abdominal ganglia at $2 \times 10^{-4}M$ blocked conduction from cercal nerves to giant fibres in 50–97 minutes and at $4 \times 10^{-5}M$ decreased the post-synaptic response; applied to giant fibres at $2 \times 10^{-4}M$, it

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blocked conduction in 90–208 minutes. The effects of the larger concentration were not completely reversible. Although SKF 525-A has been widely used to study the metabolism of drugs, its direct effects on conduction in nerve axons seem not to have been noted previously.

9.10 BUTLER, C. G., CALAM, D. H. & CALLOW, R. K. (1967) Attraction of *Apis mellifera* drones by the odours of the queens of two other species of honeybees, *Apis cerana* ssp. *indica* and *Apis florea*. *Nature, Lond.* **213**, 423–424.
(For summary see No. 11.9)

9.11 ELLIOTT, M., JANES, N. F., JEFFS, K. A., NEEDHAM, P. H., SAWICKI, R. M. & STEVENSON, J. H. (1966) New insecticidal esters of chrysanthemic acid. *Proceedings of the 3rd British Insecticide and Fungicide Conference* 1965, 432–439.

The insecticidal activities of 4-allylbenzyl, 4-allyl-2,6-dimethylbenzyl, 2,4,6-trimethylbenzyl, 4-benzylbenzyl and 4-furfurylbenzyl (±)-*cis*–*trans*-chrysanthemates were compared with those of the natural pyrethrins, allethrin, dimethrin and barthrin against houseflies, mustard beetles and several other insect species. The 4-allyl- and 4-allyl-2,6-dimethylbenzyl esters were more toxic than the natural pyrethrins against houseflies, and the 4-allyl-2,6-dimethyl compound was as toxic or more so than allethrin against nearly all the insect species examined. The benzyl esters were more stable than allethrin and the natural pyrethrins, but were less well synergised by piperonyl butoxide.

9.12 FARNHAM, A. W., GREGORY, G. E. & SAWICKI, R. M. (1966) Bioassay and histochemical studies of the poisoning and recovery of houseflies (*Musca domestica* L.) treated with diazinon and diazoxon. *Bull. ent. Res.* **57**, 1, 107–116.

Newly emerged and 3-day-old houseflies (*Musca domestica* L.) of a diazinon-susceptible and a diazinon-resistant strain were treated topically with diazinon or diazoxon and examined for symptoms of poisoning and recovery at intervals up to 5 hours and at 24 hours after treatment. The effects of the posions varied with the age and strain of the flies and with the poison used. Most of the flies that became paralysed died, but some recovered, even after seeming to be dead. Of flies treated when newly emerged, more of the resistant than of the susceptible strain recovered from paralysis, and more recovered from diazoxon than from diazinon treatment. Recoveries were fewer among flies treated when 3 days old and occurred in appreciable numbers only among those of the resistant strain treated with diazoxon.

Histochemical tests on flies treated with diazoxon showed a close correlation between inhibition of cholinesterase activity in the thoracic ganglion and the external symptoms of poisoning. Inhibition was slight in apparently unaffected flies, greater in severely affected flies and total or nearly so in completely paralysed flies. Inhibition first appeared at the periphery of the ganglion and spread inwards to the centre. Flies that recovered from paralysis had normal or almost normal cholinesterase activity; partially recovered flies showed activity only in the central parts of the ganglion. Recovery of cholinesterase activity seems to occur from the centre of the ganglion outwards.

9.13 GRIFFITHS, D. C. & SCOTT, G. C. (1966) Some tests on organophosphorus and carbamate insecticides for the control of wireworms and wheat-bulb fly. *Proceedings of the 3rd British Insecticide and Fungicide Conference* 1965, 190–196.

Of fifteen experimental compounds tested in the laboratory against wireworms,

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N 2790 (*O*-ethyl *S*-phenyl ethyl phosphonodithioate) was the only material that killed as many wireworms as γ-BHC. Twelve experimental compounds were tested as seed dressings against wheat-bulb fly: plant damage was significantly decreased by Bayer 38156 (*O*-ethyl *S*-*p*-tolyl ethyl phosphonodithioate) at 0·04% active ingredient to weight of seed, trichloronate (*O*-ethyl *O*-2,4,5-trichlorophenyl ethyl phosphonothionate) at 0·04% a.i., and dichlofenthion (*O*-2,4-dichlorophenyl *O*,*O*-diethyl phosphorothioate) at 0·15% a.i.

9.14 McIntosh, A. H. (1966) An experiment on control of potato tuber blight. *Proceedings of the 3rd British Insecticide and Fungicide Conference* 1965, 177–183.

Chemicals were applied directly to the soil ridges of a growing King Edward potato crop in 1965, at rates equivalent to twice the recommended rates per acre for haulm spraying. Tuber blight was significantly decreased by June or July application of fentin acetate or triphenyl tin chloride dusts, but not by tributyl tin acetate or bis (triphenyl tin) sulphide dusts, or tetrachloroisophthalonitrile wettable powder spray. There were no signs of phytotoxicity.

The results suggest that it might be worth while applying fentin acetate or triphenyl tin chloride (or possibly tetrachloroisophthalonitrile if suitably formulated), at planting-time or crop-emergence, for possible control of tuber blight.

9.15 McIntosh, A. H. (1966) Some formulations of fungicides for control of potato blight. In: The formulation of pesticides, *S.C.I. Monogr.* No. 21, 99–108.

(1) Spores of *P. infestans*, the fungus that causes potato blight, cannot infect leaves unless they are moist. A water-repellent fungicidal spray deposit may thus control blight better than one that is easily wetted; the water repellency may also increase the resistance of the deposit to rain. Some formulations based on this idea are described.

(2) Some chemicals (anti-transpirants), such as phenyl mercury acetate and chloride, can close the stomata on leaves, and thereby decrease loss of water from leaves without a corresponding decrease in photosynthesis. When small amounts of these are added to copper oxychloride sprays, the effects on the stomata of glasshouse- and field-grown potato plants can be measured for about a week after spraying. In the hot summer of 1964, however, such sprays offered no practical advantage (increase in yield) over plain copper oxychloride.

(3) Apparent control of foliage and tuber blight in the field has been noticed on potato crops after applying granules containing the systemic aphicide disulfoton to the soil. However, disulfoton and two other systemic aphicides, menazon and dimethoate, are not systemically fungicidal to *P. infestans* in potato plants. The action of disulfoton in the field is probably indirect, untreated plants becoming more susceptible to blight when attacked by aphids, rather than treated plants becoming more resistant.

9.16 Needham, P. H. & Dunning, R. A. (1966) A preliminary survey of variation in susceptibility of *Myzus persicae*, associated with sugar beet, to organophosphorus insecticides. *Proceedings of the 3rd British Insecticide and Fungicide Conference*, 1965, 46–51.

The resistance of *Myzus persicae* (the peach-potato aphid) to organophosphorus insecticides has been reported in field populations from the U.S.A. and Europe; it has become a problem in glasshouse populations in Great Britain. About half of the sugar-beet crop is treated annually with organophosphates, so it was thought advisable to test the susceptibility of field populations of this aphid from beet and mangolds. Resistant aphids have not been reported on this crop,

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and our tests of the susceptibilities to dimethoate of *M. persicae* from the main sugar-beet growing areas of eastern England showed no resistance.

9.17 NEEDHAM, P. H., SOLLY, S. R. B. & STEVENSON, J. H. (1966). Damage to honeybee colonies (*Apis mellifera*) by insecticides in Great Britain, 1956–65. *J. Sci. Fd Agric.* **17**, 133–137.

Methods are described for detecting insecticides in dead bees. Bees received by the Chief Bee Advisory Officer of the Ministry of Agriculture, Fisheries & Food have been analysed by these methods, and it is evident that each year some are killed by insecticides. Most such happenings are in eastern England and are caused by spraying, especially from the air, with organophosphates to control aphids on pea and bean crops. The use of poison baits to kill wasps is another cause. Such happenings could mostly be prevented by taking a few elementary precautions.

9.18 PHILLIPS, F. T. & GILLHAM, E. M. (1966) The residual toxicity to insects of some DDT formulations. In: The formulation of pesticides, *S.C.I. Monogr.* No. 21, 109–121.

The effect of different formulations of DDT, particularly those of wettable powders containing amine stearate ("LOVO" spray formulant), on its residual contact toxicity on different surfaces was examined using houseflies as test insects. Each formulation was more toxic on a glass surface than on a leaf surface. On similar surfaces, wettable powder deposits formed from sprays containing up to 2½% "LOVO 192" formulant were more toxic than emulsion deposits. Increasing the amount of "LOVO 192" above 2½% decreased the toxicity of the wettable powder deposit but increased its persistence to artificial rainwashing.

Wettable powder deposits formed from sprays containing up to 2½% of "LOVO 192" and aged on excised cotton leaves at 20° in still air increased in toxicity until they were 3 weeks old, and thereafter toxicity steadily diminished.

9.19 SAWICKI, R. M., (FRANCO, M. G. & MILANI, R.) (1966) Location of the linkage groups of some of the factors causing resistance to diazinon in the SKA strain of houseflies (*Musca domestica* L.) by crosses with susceptible marker strains. *Wld Health Bull.* (In the press.)

To locate the linkage groups of the resistance factors causing resistance to diazinon of the SKA strain of *Musca domestica* L., four closely related susceptible marker strains, each carrying the recessive marker on a known linkage group, i.e. II, *bwb*; III, *ac*; IV, *ocra*; V, *ar*; were crossed in reciprocal crosses with the SKA strain. All Fls gave similar *ld–p* lines showing that there is no sex-linked or cytoplasmic inheritance. The *ld–p* lines of the SKA flies and Fls slightly overlapped, hence incompletely dominant factors are involved in the genetic control of resistance to diazinon in SKA flies.

To analyse further the factorial control of resistance and possibly to locate the linkage groups involved, the Fl heterozygous males of each reciprocal cross were test-crossed with the females of the marker strains, and each of the two phenotypes segregating in the back-cross progeny was tested separately with diazinon. The *ld–p* lines of the two phenotypes in the progenies of the test-crosses differed only in the *ocra* and *ar* test-crosses, indicating that factors for resistance detectable in heterozygous flies are located only on the *ocra* (IV) and *ar* (V) linkage groups in the SKA strain of houseflies.

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9.20 STEVENSON, J. H. (1966) A method of obtaining active worker honeybees in winter for experimental use. *J. apicult. Res.* **5**, 63–64.

A simple method is described for activating honeybee colonies during the winter by keeping them in a heated glasshouse. Bees reared in these colonies responded like normal summer bees to dieldrin poisoning.

9.21 WAY, M. J. & HEATHCOTE, G. D. (1966) Interactions of crop density of field beans, abundance of *Aphis fabae* Scop., virus incidence and aphid control by chemicals. *Ann. appl. Biol.* **57**, 409–423.

The number of *Aphis fabae* Scop. per plant and per acre developing on field beans (*Vicia faba* L.) was inversely related to seeding rate (i.e. plant density) except sometimes at very small rates; with equal numbers of plants per acre, fewer aphids developed on plants in rows 11 in. than 22 in. apart.

Plots sown in mid-March with more than about 150,000 plants/acre were more attractive than less dense stands to colonising alate *A. fabae*, but established colonies multiplied most on the sparsest and least on the densest plots.

The number of plants per acre infected by pea leaf-roll virus was inversely related to planting density. There were more virus-infected plants on 11-in. than on 22-in. spaced rows—in contrast to the numbers of *A. fabae*. A single spray with demeton-methyl, timed to control *A. fabae*, did not significantly decrease virus incidence.

Grain yields of sprayed plots were little altered by increasing the seed rate above a critical minimum, except in one year when the densest crops lodged. Increased yields from spraying were closely related to the numbers of *A. fabae* on unsprayed plots. Dense planting (more than 400,000 plants/acre) prevented or greatly decreased losses caused by *A. fabae* in unsprayed plots except in one year when the aphids were exceptionally abundant.

Entomology Department

BOOK

10.1 LEWIS, T. & TAYLOR, L. R. (1967) *Introduction to experimental ecology*. London: Academic Press, viii, 401 pp.

GENERAL PAPERS

10.2 EDWARDS, C. A. (1966) The Swift moth as a pest growers cannot ignore. *Comml Grow.* April 1966, 783.

10.3 JOHNSON, C. G. (1966) International dispersal of insects and insect-borne viruses. *Neth. J. Pl. Path.* **72**. (In the press.)

10.4 RAW, F. (1966) The soil fauna as a food source for moles. (Ciba Foundation Symposium on Moles.) *J. Zool.* **149**, 50–54.

10.5 RAW, F. (1967) Arthropoda (except Acari and Collembola.) In: *Soil biology*, ed. N. A. Burges & F. Raw. London: Academic Press, pp. 323–362.

10.6 STEPHENSON, J. W. (1966) A resumé of recent studies of invertebrates associated with slugs. *J. econ. Ent.* **59**, 356–360.

10.7 STEPHENSON, J. W. (1967) The distribution of slugs in a potato crop. *J. appl. Ecol.* **4**, 129–135.

10.8 YOUDEOWEI, A. (1966) Feeding and aggregation in *Dysdercus intermedius* Dist. (Heteroptera, Pyrrhocoridae). *Anim. Behav.* **14**, 589.

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Research Papers

10.9 Edwards, C. A., (Dennis, E. B. & Empson, D. W.) (1966) Pesticides and the soil fauna. I. Effects of aldrin and DDT in an arable field. *Ann. appl. Biol.* (In the press.)

Aldrin dust (3 cwt of 1¼%/acre) or DDT dust (2 cwt of 5%/acre) was applied to small plots replicated four times and four plots were untreated. All plots were kept fallow for 1 year. Soil samples were taken at 2–3-monthly intervals and the fauna extracted by a flotation method. The insecticides did not affect lumbricids, enchytraeids or nematodes. Nearly 100 species of arthropods were found, and the greatest effects were those of DDT on mesostigmatid mites and of aldrin on entomobryid or isotomid Collembola and on pauropods. Most species of Collembola increased in DDT-treated plots, apparently because mesostigmatid mites were absent. In terms of biomass, Coleoptera and Diptera were most affected. Both insecticides killed more pests than predators or beneficial animals. The effects of the insecticides were greatest during late summer or autumn.

10.10 Edwards, C. A. (1966) Relationships between weights, volumes and numbers of soil animals. In: *Coll. Dynamics of Soil Communities.* Amsterdam: North-Holland Publishing Co., pp. 5–11.

A method of estimating the biomass of the microarthropods by measurement of their dimensions is outlined and the necessary data given. The average weight of all the different kinds of soil invertebrates was determined and compared with previous estimates. The specific gravities of all the various groups of soil animals were determined and proved to be very close to unity. The data are gathered together as a convenient index of animal metabolic activity in soil.

10.11 French, R. A. (1966) Migration Records 1965. *Entomologist.* (In the press.)

10.12 El Hariri, G. (1966) Records of nematode parasites of *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae). *Entomologist's mon. Mag.* **101**, 132.

10.13 Heath, G. W. & Arnold, M. K. (1966) Studies in leaf litter breakdown. II. Breakdown rate of "sun" and "shade" leaves. *Pedobiologia.* (In the press.)

Both oak leaves (*Quercus quercus*) and beech leaves (*Fagus sylvaticus*) collected at leaf-fall were arbitrarily divided into hard and soft categories. These categories were thought to be synonymous with "sun" and "shade". Discs of the selected leaves were laid on the soil surface of treated plots in oak and beech woodland. In one treatment all earthworms and their cocoons had been removed from the soil and reinvasion prevented by terylene net, and in the other they were left undisturbed. Samples of leaf discs were collected regularly and the area of leaf lamina that had disappeared estimated. The results showed that soft leaf discs disappeared more quickly than hard ones, whether earthworms could feed or not. The discs go more quickly when earthworms are present than when they are absent, and oak goes more quickly than beech. From January to June worms seem to remove more leaf material from the surface by burying it than by eating it. They prefer to bury soft leaves compared with hard ones.

10.14 Heathcote, G. D. & Cockbain, A. J. (1966) Aphids from mangold clamps and their importance as vectors of beet viruses. *Ann. appl. Biol.* **57**, 321–336.
(For summary see No. 16.7)

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10.15 LEWIS, T. & STEPHENSON, J. W. (1966) The permeability of artificial windbreaks and the distribution of flying insects. *Ann. appl. Biol.* **58**, 355–363.

The number of flying insects in the sheltered zone to leeward of artificial windbreaks of 0, 25, 45 and 70% permeability was greater than in unsheltered areas. Insects accumulated nearer to dense windbreaks than to more permeable ones, and the position of maximum aerial density of insects coincided with that of maximum shelter. The more dense the windbreak, the greater the numbers in the air to leeward. Absolute wind speed slightly affected the position of maximum aerial density behind a 45% permeable fence.

10.16 LEWIS, T. (1966) Artificial windbreaks and the distribution of turnip mild yellows virus and *Scaptomyza apicalis* (Diptera) in a turnip crop. *Ann. appl. Biol.* **58**, 371–376.

In a turnip crop natural infection with turnip mild yellows virus was greatest in two narrow zones, one to leeward of an artificial windbreak, the other in a long shallow depression in the earth. Both zones were approximately across wind when *Myzus persicae* flew in early summer. Later in the summer similar windbreaks facing different prevailing winds caused an increase in the number of larvae of *Scaptomyza apicalis* on the plants immediately to leeward and windward of the windbreaks, probably because shelter affected adults that were flying and laying eggs in the crop.

10.17 LEWIS, T. (1966) An analysis of components of wind affecting the accumulation of flying insects near artificial windbreaks. *Ann. appl. Biol.* **58**, 365–370.

Flying Cecidomyiidae, Mycetophilidae and Aphididae accumulated to leeward of a windbreak of 45% open area. There were relatively more of these insects in sheltered than in unsheltered air the greater the angle of the incident wind to the windbreak, and the greater the free wind speed. Mycetophilidae and Aphididae accumulated relatively less as turbulence in the free air increased. The accumulation of Myrmaridae to leeward of a solid windbreak was affected only by wind speed. No relationship was detected between the accumulation of Psychodidae, parasitic Hymenoptera, Thysanoptera and Staphylinidae and the incident angle of wind, wind speed or turbulence.

10.18 STEPHENSON, J. W. (1966) Notes on the rearing and behaviour in soil of *Milax budapestensis* (Hazay). *J. Conch., Lond.* **26**, 141–145.

An open-textured medium is necessary for the culture of *M. budapestensis*, which can be cultured at 20° C when fed with sliced carrot or potato, and which grows faster at that temperature than at 5° or 10° C. Individuals from the same egg batch grow at very different rates. Egg laying is inhibited by a constant temperature of 20° C and stimulated by temperatures fluctuating between 10° and 20° C. Field and laboratory investigations showed that this slug can burrow through heavy soil by ingesting it. Cavities, in which eggs were laid, can be excavated in hard lumps of soil.

10.19 YOUDEOWEI, A. (1967) The reactions of *Dysdercus intermedius* Dist. (Heteroptera, Pyrrhocoridae) to moisture, with special reference to aggregation. *Ent. exp. & appl.* (In the press.)

The behaviour of *Dysdercus intermedius* Dist. in a humidity gradient and in moist/dry choice chambers was studied in the laboratory. *D. intermedius* perceived and responded to atmospheric humidity by means of two types of hygroreceptors on the antennae. A preference for moist air during early larval life

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changed to one for dry air by the later larvae and adults. The formulation or dissolution of aggregations was determined by the wetness of the substrate and not by atmospheric humidity.

Bee Department

Book

11.1 Butler, C. G. (1967) *The world of the honeybee*. Revised edition. (New Naturalist Series.) London: Collins, xiv, 226 pp.

General Papers

11.2 Bailey, L. (1966) Pathogens of wax moths and other insects. *Rep. cent. Ass. Br. Beekeep. Ass.*, pp. 1–8.

11.3 Butler, C. G. (1967) Insect Pheromones. *Biol. Rev.* **42**, 42–87.

11.4 Free, J. B. (1966) The foraging behaviour of bees and its effect on the isolation and speciation of plants. In: *Reproductive biology and taxonomy of vascular plants*, ed. J. G. Hawkes. London: Pergamon Press, pp. 76–92.

11.5 Free, J. B. (1966) Seasonal regulations in the honeybee colony. In: *Regulation and control in living systems*, ed. H. Kalmus. London: Wiley, pp. 351–379.

11.6 Free, J. B. (1966) Studies on honeybee pollination of fruit flowers. *Proc. 2nd int. Symp. on Pollination* (*London*) 1964. Suppl. to *Bee World* **47**, 95–96.

11.7 Free, J. B. & (Ellis, P. E.) (1964) Social organisation of animal communities. *Nature, Lond.* **201**, 861–863.

Research Papers

11.8 Butler, C. G. (1966) Mandibular gland pheromone of worker honeybees. *Nature, Lond.* **212**, 530.

Contrary to suggestions that have been made, the secretion of the mandibular glands of worker honeybees neither attracts other workers nor acts as a weak alerting pheromone. It repels foragers, but its precise biological function remains a matter for conjecture. The pheromone concerned seems to be 2-heptanone.

11.9 Butler, C. G., Calam, D. H. & Callow, R. K. (1967) Attraction of *Apis mellifera* drones by the odours of the queens of two other species of honeybees, *Apis cerana* ssp. *indica* and *Apis florea*. *Nature, Lond.* **213**, 423–424.

Odours of queens of the honeybees *Apis cerana* ssp. *indica* and *A. florea* attract drones of *A. mellifera* and produce 9-oxodecenoic acid, the olfactory sex attractant of *A. mellifera*. It is probable, but not yet certain, that 9-oxodecenoic acid is the sex attractant of all species of honeybees.

11.10 Free, J. B. (1965) The ability of bumblebees and honeybees to pollinate red clover. *J. appl. Ecol.* **2**, 289–294.

The pollinating efficiency of honeybees and bumblebees when visiting red clover flowers was determined. The percentage of florets visited that set seed decreased rapidly with the number of days they had been open. There was little or no difference between the pollinating efficiency of honeybees and different species of bumblebees when both entered the florets. The number of florets visited per

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head depended on their supply of nectar and pollen. Pollen-gatherers tended to visit more florets per head and to be more efficient pollinators than nectar-gatherers. The percentage of visited florets that set seed did not vary with the number visited per head.

11.11 FREE, J. B. (1966) The pollinating efficiency of honeybee visits to apple flowers. *J. hort. Sci.* **41**, 91–94.

Bees scrabbling for pollen set a greater percentage of the flowers they visit than bees collecting nectar. The pollinating efficiency of visits is much greater to self-compatible than to self-incompatible varieties, on which the efficiency decreases as distance from the source of compatible pollen increases. Calculations indicate that one colony of honeybees probably provides enough foragers to pollinate sufficient flowers to give an economic set in an acre of apple orchard.

11.12 FREE, J. B. (1966) The pollination requirements of broad beans and field beans (*Vicia faba*). *J. agric. Sci., Camb.* **66**, 395–397.

Broad-bean plants caged with bees produced more seeds per pod, more seeds per plant, heavier seeds and a greater weight of seeds per plant than plants caged without bees. They also had more mature pods at the first harvest, but the total number of pods picked was about the same for cages with and without bees. The flowering season of plants caged without bees was extended. Field-bean plants caged with bees had more seeds per pod and more seeds per plant than plants without bees.

11.13 FREE, J. B. & DURRANT, A. J. (1966) The dilution and evaporation of the honey-stomach contents of bees at different temperatures. *J. apicult. Res.* **5**, 3–8.

Worker honeybees were kept in cages at different temperatures and provided with water and with different concentrations of sugar syrup. Their food consumption and the amount and concentration of the contents of their honey-stomachs were determined. The amount of sugar syrup consumed increased as the temperature decreased. More water was consumed in those cages with the more concentrated syrup. At 20.0–27·5° C the bees diluted food in their honey-stomachs with saliva, the dilution being greatest with the more concentrated food. At 30·0–37·5° C the bees still diluted their food and showed an increased water consumption, but, because they evaporated water on their mouthparts (especially at 37·5° C), the honeystomach contents were more concentrated.

11.14 FREE, J. B. & DURRANT, A. J. (1966) The transport of pollen by honey-bees from one foraging trip to the next. *J. hort. Sci.* **41**, 87–89.

Some bees leaving their hives still carry viable pollen collected on a previous trip and can fertilise any compatible flower they visit.

11.15 SIMPSON, J. (1966) Congestion of adult bees with and without adequate hive space. *J. apicult. Res.* **5**, 59–61.

When colonies were given hives too small to hold all their bees the density of the bees that managed to get into the hives was 2½–3½ times normal. Removal of part of the brood from colonies increased the bee density on the remaining brood; this behaviour may increase the likelihood of swarming by colonies with plenty of hive space.

11.16 SIMPSON, J. (1966) Repellency of the mandibular gland scent of worker honeybees. *Nature, Lond.* **209**, 531–532.

Crushed foraging bees' heads, containing the strongly smelling mandibular gland secretion, repelled flying foragers from dishes of sugar syrup, but the

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function of the scent is not to divert bees away from exhausted food sources, as these proved more attractive than unexhausted ones. The scent may enable robbing bees to avoid strong colonies, or it may play a part in regulating brood feeding.

Statistics Department

Research Papers

12.1 (Barron, S. L.) & Vessey, M. P. (1966) Birth weight of infants born to immigrant women. *Br. J. prev. soc. Med.* **20**, 127–134.

The birth weights of 3,656 British, 636 Irish, 833 West Indian and 158 Cypriot infants born at Lambeth Hospital in the years 1958–60 were compared. Maternal country of origin was taken to indicate the nationality of the infant.

The differences between the birth weight means of the British, Irish and Jamaican infants were not explained by nationality differences in social class, birth rank distribution, maternal height and weight or duration of gestation. Information concerning duration of gestation was, however, rather inaccurate and that concerning maternal body weight was very incomplete.

12.2 Boyd, D. A., Hill, J. R. & (Batey, T.) (1967) The effect on yield of maincrop potatoes of different methods of fertiliser application. *Expl Husb.* (In the press.)

Grouping the results of manurial experiments on maincrop potatoes according to method of fertiliser application showed that each nutrient was used more efficiently on sites where the fertilisers were applied "over the ridges" than where they were broadcast "on the flat". When fertilisers were applied "on the flat" 50% more fertiliser was needed to obtain the same responses as from application "over the ridges". However, only 150–180 units K_2O/acre could be safely applied "over the ridges"; larger dressings decreased yields.

In most, but not all, of the published results of experiments with compound fertilisers, the effect of sideband placement was similar to that of application "over the ridges". Fertiliser broadcast "on the flat" was equally effective whether worked into the seed-bed or applied immediately before planting.

With efficient methods of application, care should be taken not to use too much N when potatoes follow a ley.

12.3 (Chisci, G. C.) & Martin, A. H. (1967) The use of discriminant functions in intraspecific classification of lucerne. *Genet. agr.* (In the press.)

The possibility of using linear discriminant functions of leaflet length and width as an objective method for classifying North Italian cultivars of lucerne, using five sets of results from three centres, Torino, Lonigo and Lodi, was investigated. The general behaviour of the discriminators differs from centre to centre, but certain consistencies are observed within the three Torino sets. There is, however, no indication that any of the discriminators could give valid classifications if applied to further observations whether taken at the same centre or not.

12.4 (Delany, M. J.) & Healy, M. J. R. (1967) Variation in the long-tailed field-mouse (*Apodemus sylvaticus* (L.)) in the Channel Islands. *Proc. R. Soc.* B. **166**, 408–421.

Measurements of 10 skull characters on 352 specimens of *Apodemus sylvaticus* (L.) from five of the Channel Islands, two localities in southern England and one in northern France, and 37 specimens of *A. flavicollis* (Melch.) from southern

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England were analysed, keeping the sexes separate and adjusting the measurements to take account of age estimated from a measurement of tooth wear. Four canonical variates accounted for almost all the variance. From these it appeared that the populations separated into three groups, the first containing the mainland mice from Hampshire, Cornwall and Cap Gris Nez, the second those from the Channel Islands and the third the collection of *A. flavicollis*.

The analysis confirms that in the British Isles *A. flavicollis* is distinct from *A. sylvaticus* and that the Channel Island mice, although larger than the mainland *A. sylvaticus*, probably belong to that species. Differences between populations from the Channel Islands are small, although the mice from Herm and Sark are relatively large. The Channel Island mice may have derived from a common stock.

12.5 GOWER, J. C. (1966) Some distance properties of latent root and vector methods used in multivariate analysis. *Biometrika* **53**, 325–338.

This paper is concerned with the representation of a multivariate sample of size n as points $P_1, P_2, \ldots P_n$ in a Euclidean space. The interpretation of the distance $\Delta(P_i, P_j)$ between the ith and jth members of the sample is discussed for some commonly used types of analysis (including both Q and R techniques). When all the distances between n points are known a method is derived which finds their co-ordinates referred to principal axes. A set of necessary and sufficient conditions for a solution to exist in real Euclidean space is found. Q and R techniques are defined as being dual to one another when they both lead to a set of n points with the same inter-point distances. Pairs of dual techniques are derived. In factor analysis the distances between points whose co-ordinates are the estimated factor scores can be interpreted as D^2 with a singular dispersion matrix.

12.6 GOWER, J. C. (1966) A Q-technique for the calculation of canonical variates. *Biometrika* **53**, 588–589.

A Q-technique for evaluating canonical variates is described. It has computational and statistical advantages over the usual R-technique.

12.7 GOWER, J. C. (1967) Multivariate analysis and multidimensional geometry. *The Statistician*. (In the press.)

Many multivariate statistical methods may be regarded as techniques for investigating a sample space in which each sample number is represented by a point. Some aspects of the geometrical interpretation of Principal Components, Principal Coordinates, Canonical Variate and Factor Analysis are discussed, with stress given to implicit assumptions not always realised; some special cases of principal components analysis are included. The angular representation of samples is discussed and the inter-relationship between the hierarchical representation of a sample and its spatial representation briefly described.

12.8 GOWER, J. C. (1967) Autocode requirements for the statistician. *Appl. Statist.* (In the press.)

Statisticians have been forced to write statistical systems of programmes because of inadequacies in existing algebraic autocodes. Statistical systems have many disadvantages and the alternative approach of improving the autocodes is considered. A few extensions, particularly in the direction of accepting more types of operand and in storing and recovering programme and data, would greatly improve the power and flexibility of autocode. With the suggested improvements statistical systems would need no special programming, as all the facilities needed would be provided at the autocode level.

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12.9 GOWER, J. C., SIMPSON, H. R. & MARTIN, A. H. (1967) A statistical programming language. *Appl. Statist.* (In the press.)

The programming language described was designed to handle many of the problems arising in the statistical analysis of data. It incorporates many of the features found in other algebraic autocodes, but these are generalised to permit operations on multiway tables or parts of tables as well as single variables. There are comprehensive input and output facilities and special automatic provision for the input of survey data. Data and previously compiled programs can be stored on magnetic tape and readily incorporated into further programs.

12.10 LESSELLS, W. J. & (FRANCIS, A. L.) (1967) The crossbred progeny test of beef bulls. *Expl Husb.* (In the press.)

The progeny of 39 Hereford bulls, representative of those standing at A.I. centres, and which had already been performance tested, were reared in four intakes at Rosemaund and High Mowthorpe Experimental Husbandry Farms. For each bull an average of six progeny, all out of Friesian-type dams, were tested at each centre. Progeny were autumn born and were taken through to slaughter at a liveweight of 8½–9 cwt; the average age at slaughter was 17 months.

Rates of liveweight gain of progeny were predicted as accurately from sire performance up to weaning (181 days) as from the whole period of their test (400 days). Average values of heritability (h^2) were 35–40%, the estimates being subject to large errors. Differences in efficiency of food conversion of both sires and progeny were slight, variation in liveweight gain being largely determined by differences in food intake.

The policy of slaughtering at a constant weight made the estimates of killing-out percentage and carcass grading of little value because the faster-growing progeny were not only younger but probably also less well finished. Other deficiencies in the design of this experiment are discussed.

12.11 LEWIS, J. A. (1967) A program to fit constants to multiway tables of quantitative and quantal data. *Jl R. statist. Soc.* B. (In the press.)

The paper describes a program for the analysis of multiway tables of quantitative and quantal data with disproportionate frequencies, by fitting additive parameters. For quantitative data the parameters are obtained by the inversion of the coefficient matrix of the normal equations. Quantal values are first transformed by the logit transformation, and a similar iterative procedure is used. Various systems of parameters can be fitted; their standard errors and an analysis of variance table are provided. Input can be from magnetic or paper tape, and in certain cases complete tables are not required. An example of the analysis of quantal data by the program concludes the paper.

12.12 PREECE, D. A. (1966) On Addelman's 2^{17-9} Resolution V Plan. *Technometrics* **8**, 705–707.

A concise representation is given of a 2^{17-9} resolution V plan of Addelman, and a connection is described between that plan and certain partially balanced incomplete block designs with two associate classes.

12.13 PREECE, D. A. (1966) Some balanced incomplete block designs for two sets of treatments. *Biometrika* **53**, 477–506.

This paper describes and lists certain block designs for two non-interacting sets of treatments. The designs have the following properties: (*a*) each set of treatments is arranged relative to blocks in a non-symmetrical balanced incomplete block design, the same balanced incomplete block solution being used for both sets of treatments; (*b*) each set of treatments is totally balanced with respect to

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the other, i.e. each is disposed relative to the other in the same way that treatments are disposed relative to blocks in a balanced incomplete block design; (*c*) the number of replications of each treatment of each set is either one more than or one fewer than the number of treatments in the set; and (*d*) the designs are balanced, in the sense that the variance of an estimated difference in effect between two treatments from the same set is independent of the treatments compared.

12.14 YATES, F. (1966) Computers, the second revolution in statistics. (The First Fisher Memorial Lecture.) *Biometrics* **22**, 233–251. (Italian text: *Bollettino per le applicazioni biomediche del calcolo elettronico*, No. 4, 149–166 (1966).)

The paper gives examples of the ways in which electronic computers are improving the quality and speed of statistical analyses previously done on desk calculators and punched-card machines and are making available and extending analytical methods—many of them due to Fisher—previously impracticable for routine use. Statistical applications of computers have, however, developed slowly. Reasons for this are sought. There is urgent need for further development of general programs able to handle a wide range of statistical problems. Such programs should be written in some commonly acceptable autocode and widely disseminated so they can be used by statistical research workers on the various types of computers, at universities and in research organisations. Many of the current statistical programs are unsatisfactory.

12.15 YATES, F. & ANDERSON, A. J. B. (1966) A general computer programme for the analysis of factorial experiments. *Biometrics* **22**, 503–524.

A general programme for the analysis of factorial experiments is described, written in Extended Mercury Autocode for the I.C.T. Orion computer at Rothamsted. It can deal with experiments with up to seven factors, including those with complete or partial confounding and multiple splits, arranged in randomised blocks, Latin or quasi-Latin squares, or criss-cross designs. Partially confounded contrasts have to be specified by the user, but for the commoner types of design the correct arrangement of the analysis of variance is provided automatically. Properly adjusted tables of treatment means are produced, and covariance and missing values are provided for.

An outline of the least-square theory of confounded designs is appended. Improvements incorporated in a revised version of the programme are described in an addendum.

Field Experiments Section

RESEARCH PAPERS

13.1 GARNER, H. V. (1966) Experiments on the direct, cumulative and residual effects of town refuse manures and sewage sludge at Rothamsted and other centres 1940–47. *J. agric. Sci., Camb.* **67**, 223–233.

Several town refuse manures and a digested sewage sludge were compared with farmyard manure in single and double dressings with and without fertiliser nitrogen and potash. The refuse experiments measured direct and residual effects, the sludge experiments showed the cumulative effects of dressings repeated on the same plots for 4 years. Averaging all root crops, pulverised refuse gave 64% of the effect of farmyard manure in the year of application; for screened dust the figure was 52%. After one crop had been grown the residues of pulverised refuse gave 70% of the corresponding farmyard manure effect;

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screened dust 52%. The interaction between farmyard manure and fertiliser potash was always negative, but with ammonium sulphate farmyard manure sometimes gave a positive interaction. Similar but smaller effects were often observed with the other organics. Horticultural crops grown on rich soils gave smaller responses to the organic manures than the agricultural crops, but again farmyard manure was the most effective.

In the cumulative experiments sewage sludge was much inferior to farmyard manure for potatoes and carrots on a sandy soil deficient in potash, but on a heavy soil where nitrogen was the main requirement sewage sludge was as good as, and sometimes better than, farmyard manure. After 4 years both organics produced large effects in potatoes and sugar beet grown without further manure. There were also cumulative effects from muriate of potash with potatoes and from superphosphate with sugar beet. Beet tops were slightly increased on plots that had received repeated dressings of ammonium sulphate.

13.2 GARNER, H. V. (1966) Comparisons of farmyard manure, sewage sludge and other organic manures tested on potatoes and a succeeding cereal crop at Rothamsted. *J. agric. Sci., Camb.* **67**, 267–280.

Eight kinds of farmyard manure (FYM) made under controlled conditions were compared with sewage sludges, sludge–straw composts, town refuses, stacked bracken and peat. The organic manures were used at single and double rates with and without fertilisers. Potatoes were grown in the year when the manures were applied and were followed by unmanured cereals. Potatoes responded to all fertilisers, especially to K; the yearly increase from FYM was closely related to the degree of response to K. For potatoes fresh FYM was better than stored; extra straw for litter was beneficial only when the manure was made in open yards and stored in the open for a year. The interactions between the organic manures and fertiliser nutrients suggested that sludges provided much N but little K, and dried bracken was a good source of K.

Cereals benefited considerably from FYM applied to potatoes and more from fresh FYM than from stored FYM. Sludges and their compost had about half the residual effect of FYM and town refuses about one-fifth.

Broom's Barn Experimental Station

THESIS

16.1 BYFORD, W. J. (1966) A study of the biology of sugar-beet downy mildew caused by *Peronospora farinosa* (Fr.) Fr. Ph.D. Thesis, University of London.

GENERAL PAPERS

16.2 DRAYCOTT, A. P. (1966) Fertilisers for sugar beet. *Fmg Wld* March.

16.3 DUNNING, R. A. (1966) Mangold clamps, aphids and virus yellows. *Brit. Sug. Beet Rev.* **34**, 124–126 and **35**, 24.

16.4 HEATHCOTE, G. D. (1966) Answers on the way to combat Docking problem. *Fmg Wld* Agricultural supplement, March.

16.5 TINKER, P. B. H. (1966) Magnesium deficiency. *Brit. Sug. Beet Rev.* **34**, 171–174.

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Research Papers

16.6 Draycott, A. P. & Cooke, G. W. (1967) The effects of potassium fertilisers on quality of sugar beet. *Potass. Symp.* 1966. (In the press.)

In more than 500 sugar-beet experiments extending over nearly 30 years, potassium manuring increased sugar content of the roots slightly but consistently. Noxious-nitrogen was consistently diminished by potassium, but much more in the early experiments than in the later ones. Juice purity was little affected by potassium manuring. The effects of potassium fertilisers on beet quality are much smaller than those of nitrogen fertilisers and are comparatively unimportant in practice, but they are beneficial.

16.7 Heathcote, G. D. & Cockbain, A. J. (1966) Aphids from mangold clamps and their importance as vectors of beet viruses. *Ann. appl. Biol.* **57**, 321–336.

Mangold clamps are overwintering sources of aphid-transmitted viruses and of several species of aphid, the most common being *Myzus persicae*, *Rhopalosiphoninus staphyleae* and *R. latysiphon*. Alate *M. persicae* and *R. staphyleae* become common in clamps during April, but few fly below 15° C, and flight muscle autolysis probably also prevents many alatae from flying in early spring. *R. staphyleae* and *R. latysiphon* are seldom trapped in flight.

Clamps can be an important source of beet viruses, and *M. persicae* is probably responsible for most spread of virus. *R. staphyleae* did not transmit beet mosaic virus, but is a fairly efficient vector of beet yellows and beet mild yellowing viruses. *R. latysiphon* did not transmit any of the beet viruses, and the role of the other species of aphids occasionally found in mangold clamps is probably small.

16.8 Heathcote, G. D., Greet, D. N. & Whitehead, A. G. (1966) Effect of fumigating sandy soil on the growth of sugar beet. *Pl. Path.* **15**, 120–124.

Treating soil with "D-D" or chloropicrin gave beet plants with normal foliage, and greatly increased root yield in a field in Norfolk where otherwise beet were stunted and apparently deficient in nutrients. At Broom's Barn, where beet grew normally on untreated soil, fumigation with "D-D" increased the number of seedlings emerging but also gave many poor roots. "D-D" was also damaging at the dosage used at the other site, but chloropicrin gave a yield of normal roots. Fumigation of sandy soil prone to give plants with Docking disorder may be worth while when it can be done cheaply.

16.9 Needham, P. H. & Dunning, R. A. (1966) A preliminary survey of variation in susceptibility of *Myzus persicae*, associated with sugar beet, to organophosphorus insecticides. *Proceedings of the 3rd British Insecticide and Fungicide Conference* 1965, 46–51.
(For summary see No. 9.16)

16.10 Tinker, P. B. H. (1967) The effects of magnesium sulphate on sugar-beet yield and its interactions with other fertilisers. *J. agric. Sci., Camb.* (In the press.)

Magnesium deficiency symptoms in sugar beet have increased recently. In 17 trials on fields where magnesium deficiency was expected, 5 cwt/acre of kieserite gave a mean response of 3·7 cwt/acre of sugar. Magnesium slightly increased the yield of tops, and either did not affect, or improved, juice purity and sugar percentage.

The most profitable nitrogen dressing was about 1·2 cwt/acre N. Sodium and

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potassium fertilisers increased yield by 3·4 and 2·7 cwt/acre of sugar respectively. Magnesium and nitrogen interacted negatively in top yield, and to a smaller extent in sugar yield. With the large N dressing, magnesium decreased top weight slightly, but increased sugar yield by 3·1 cwt/acre on average. Magnesium did not alter the mean response to sodium or potassium, but where magnesium considerably increased sugar yield, sodium given without magnesium decreased yield.

Large yield responses to Mg fertiliser are likely only where more than 20% of the beet show symptoms. Deficiency symptoms were cured or ameliorated by magnesium, slightly decreased by nitrogen and increased by sodium fertilisers.

All trials were on light, sandy soils, mainly on the Worlington, Moulton or Freckenham series. The concentration of Mg in a 0·01*M* solution of $CaCl_2$ equilibrated with the soil was fairly well related to yield responses to Mg, but exchangeable Mg was not, though it was small in all the soils where responses were found.

16.11 TINKER, P. B. H. & BOLTON, J. (1966) Exchange equilibria of sodium on some British soils. *Nature, Lond.* **212**, 548.

The relationships of the activity ratio $\frac{a_{Na}}{\sqrt{a_{(Ca + Mg)}}}$ (AR_{Na}) to the amounts of exchangeable sodium in several British soils was investigated. A peat soil gave a straight-line relationship, but with mineral soils the line was curved at very small values of the activity ratio. This is thought to indicate "preferred sites" where Na is held more strongly than on the rest of the exchange complex; these sites were less than 0·6% of the exchange capacity in the soils tested. The slopes of the AR_{Na}–exchangeable sodium graphs were very much smaller than the corresponding values for potassium.

16.12 WAY, M. J. & HEATHCOTE, G. D. (1966) Interactions of crop density of field beans, abundance of *Aphis fabae* Scop., virus incidence and aphid control by chemicals. *Ann. appl. Biol.* **57**, 409–423.
(For summary see No. 9.21)

Soil Survey of England and Wales

BOOKS

17.1 BRIDGES, E. M. (1966) *The soils and land use of the district north of Derby*. Harpenden: Rothamsted Experimental Station, vii, 112 pp.

17.2 CROMPTON, E. (1966) *The soils of the Preston district of Lancashire*. Harpenden: Rothamsted Experimental Station, vii, 128 pp.

17.3 MACKNEY, D. & BURNHAM, C. P. (1966) *The soils of the Church Stretton district of Shropshire*. Harpenden: Rothamsted Experimental Station, vii, 247 pp.

THESIS

17.4 RUDEFORTH, C. C. (1966) The nature, distribution and origin of the soils of mid-Wales. M.Sc. Thesis, University of London.

GENERAL PAPERS

17.5 ASHLEY, G. D. & (JOHNSON, W.) (1966) Improvement of upland grazing at West Greenridge, Hexham. *Northumbrian Farmer* 10–12.

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17.6 CRAMPTON, C. B. (1966) Analysis of pollen in soils on the peaks of south Wales. *Scott. geogr. Mag.* **82**, 46–52.

17.7 CRAMPTON, C. B. (1966) Hill soils and grasslands in Brecknockshire: a study of potential land use. *J. Br. Grassld Soc.* **21**, 70–79.

17.8 CRAMPTON, C. B. (1966) Soils, forests and pastures in South Wales. *Forestry* **39**, 171–188.

17.9 KING, D. W. (1966) The soils. In: *Northaw Great Wood, its history and natural history*. Hertfordshire County Council.

7.10 TOMLINSON, P. R. (1965) Soils of Northern Nigeria, a generalized account of their distribution and contemporary classification. *Rep. Inst. agric. Res., Samaru 1963–4*, 51–62.

RESEARCH PAPERS

17.11 CRAMPTON, C. B. (1966) Certain effects of glacial events in the vale of Glamorgan, South Wales. *J. Glaciol.* **6**, 261–266.

In South Wales there is evidence for two phases of intense glaciation and an interglacial phase during the Pleistocene. During the closing stages of the earlier glaciation in the west of the Vale of Glamorgan two overflow channels were cut by melt water from an ice lobe off the Glamorgan upland, abutting against ice from the Irish Sea. During retreat, ice from the Irish Sea and local ice deposited material on the Lower Lias outcrop on which two contrasting soils developed. Soils usually associated with a Mediterranean climate developed locally on the outcrop of the Carboniferous Limestone during the interglacial phase.

17.12 CRAMPTON, C. B. (1966) An interpretation of the pollen and soils in cross-ridge dykes of Glamorgan. *Bull. Bd Celtic Stud.* **21**, 376–390.

Pollen in soils buried beneath selected cross-ridge dykes in the Glamorgan upland is used to date their construction by reference to a standard established earlier. Pollen analyses suggest the dykes were built in heathland vegetation and thus help to confirm their early Medieval construction. Simultaneously, a study of the internal morphology of the dykes in terms of their soils, by reference to the surrounding soils, provides some information about the historical developments of soils in the region.

17.13 (MAYCOCK, P. F.) & MATTHEWS, B. (1966) An arctic forest in the tundra of northern Ungava, Quebec. *Arctic* **19**, 114–144.

An extensive willow thicket community containing *Salix* of tree size was discovered in a river valley 32 miles south-east of Deception Bay in northern Ungava. Ecological studies were conducted to determine compositional and environmental features. The development and persistence of the community is discussed in relation to the existing climate and glacial history of the region as it is understood at present.

MAPS

17.14 CROMPTON, E., KING, D. W., TAPP, C. J., MACKNEY, D., ASHLEY, G. D. & HALL, B. R. (1966) *Soil Map, 3rd Edition Sheet 75 (Preston)* 1: 63,360. Southampton: Ordnance Survey.

17.15 GREEN, R. D., (ASKEW, G. P.) & HODGSON, J. M. (1966) *Soil Map of Romney Marsh* 1: 25,000. Southampton: Ordnance Survey.

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17.16 MACKNEY, D. & BURNHAM, C. P. (1966) *Land Capability Map 3rd Edition Sheet 166* (*Church Stretton*) 1: 63,360. Southampton, Ordnance Survey.

17.17 (TAVERNIER, R., DUDAL, R.), OSMOND, D. A. & (MOORMAN, F.) (1966) Soil Map of Europe 1: 2,500,000. Food and Agricultural Organisation of the United Nations.

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