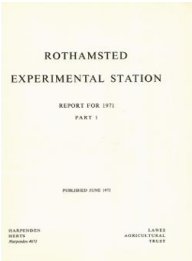
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ROTHAMSTED RESEARCH

Report for 1971

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Rothamsted Research

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Physics Department

Thesis

1.1 Rowse, H. R. (1971) The movement of water in plants. Ph.D. Thesis, University of London.

General Papers

1.2 Penman, H. L. (1972) Weather 1970. *Transactions of Hertfordshire Natural History Society* **28**. (In the press.)

1.3 Penman, H. L. (1972) Why do irrigation experiments? In: *Symposium on irrigation experimentation, Wellesbourne, March 1971.* (In the press.)

Research Papers

1.4 Lake, J. V. (1971) The behaviour of plants in various gas mixtures. *Proceedings of the Royal Society* (*B*) **179**, 177–188.

The effects of the composition and pressure of the ambient gas mixtures on the diffusive gas exchange of leaves, and the effects of carbon dioxide and oxygen on respiration and photosynthesis are described. When photosynthesis is limited by the rate at which carbon dioxide reaches the chloroplasts, the net rate of photosynthesis of many (but not all) plant species depends on the ambient oxygen partial pressure. The effect of oxygen may be principally to stimulate a respiratory process rather than to inhibit carboxylation. However, when photosynthesis is not limited by the carbon dioxide supply, this respiratory process seems to be suppressed.

The gas exchange of plant communities responds to the aerial environment in the way expected from measurements on single leaves, but the growth response to a given difference in gas composition is smaller than expected because of adaptation, notably in the ratio of leaf dry mass to leaf area.

It is concluded that the growth rate of higher plants in given illumination will be independent of the partial pressure of oxygen and of other gases likely to be used to dilute it, provided that the carbon dioxide partial pressure is so adjusted (probably to not more than 2 mb) that the rate of photosynthesis is not limited by the rate of diffusion to the chloroplasts.

1.5 Lake, J. V. (1971) Comparison of natural and artificial sources of light. *Proceedings of the Royal Society* (*B*) **179**, 189–192.

The area of crop plants required to sustain a man in an artificial extra-terrestrial environment is probably about 10 m^2. If the site is on the Moon, the natural light will alternate with periods of darkness, but will be brighter than any practicable arrangement of artificial lights. The latter can, however, be run continuously.

To control plant temperature, an artificial cooling system will be required with either kind of illumination. The energy to be dissipated will be about 700 W m^{-2} with natural light, or three times this amount with artificial light (high pressure discharge lamps).

1.6 Lake, J. V. (1972) Gas exchange of field crops. In: *Crop processes in controlled environments*. A. R. Rees and others. London: Academic Press.

The aims of crop gas exchange studies are reviewed and it is concluded that the relation between net rate of carbon dioxide uptake and economic yield and the possible existence of an optimum water-use efficiency for some crops could both usefully be the subject of direct experiment.

Techniques for estimating rates of crop gas exchange are compared; there seems to be scope for progress in estimating crop gas exchange in given weather from physiological attributes of the foliage canopy as a whole, measured with the use of a transparent enclosure, and from a measurement of the proportion of ground covered by the foliage.

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1.7 LEGG, B. J. & LONG, I. F. (1972) Microclimatic factors affecting evaporation and transpiration. In: *Soil water physics and technology*. International Society of Soil Science. Rehovot, August 1971.

A computer model of the crop canopy makes it easier to understand the interaction between the atmosphere and the crop. A five level resistance model requires profiles of net radiation, leaf area index, wind speed, stomatal resistance and turbulent diffusivity (K), and the values of soil heat flux, and air temperature and humidity above the crop. It calculates the evaporation and heat flux from each layer and the profiles of temperature and humidity inside the canopy.

The turbulent diffusivity in wheat was studied by supplying a uniform flux of N_2O at ground level, and measuring the concentration profile:

(i) K values calculated from the energy balance and N_2O profile were not systematically different, supporting the hypothesis that K is the same for gas and heat transfer inside the crop.

(ii) Below the flag leaf layer, K was not significantly dependent on wind speed, but was on the temperature gradient. The possible errors in evaporation estimates caused by treating K as a function of wind speed only are investigated with the computer model.

(iii) The one dimensional assumption may be an oversimplification because wind speed was constant below the flag leaves, and there were horizontal variations of N_2O concentration. The calculated horizontal fluxes were frequently large compared with the vertical flux, though this may have been caused by the very dense canopy.

1.8 PARKINSON, K. J. & LEGG, B. J. (1972) A continuous flow porometer. *Journal of Applied Ecology* **8**. (In the press.)

A porometer was made that uses a continuous measured flow (V) of dry nitrous oxide into a porometer cup attached to a known leaf area (A). The gas within the cup is well stirred and the humidity of the outgoing gas is measured with an aluminium oxide sensor. There is a simple relationship between stomatal resistance (r_s), aerodynamic resistance (r_a), the outgoing gas vapour pressure (e_2), and leaf temperature represented by the saturation vapour pressure, e_3, at that temperature, such that

$$(r_a + r_s) = A(e_3/e_2 - 1)/V$$

The advantages of this porometer are that it gives continuous readings, has a short response time and is easy to calibrate.

1.9 (PASSIOURA, J. B.) & ROSE, D. A. (1971) Hydrodynamic dispersion in aggregated media: II. Effects of velocity and aggregate size. *Soil Science* **111**, 345–351.

Measurements of dispersion coefficients in three aggregated materials are in accord with the theory presented in Part I of the series. In particular, it is shown (i) that for a given salt in a given material the dispersion coefficient (K) is uniquely related to the product of velocity and aggregate size (Ua), (ii) that this relation approaches $K(Ua)^2$ for large Ua, (iii) that for a given material there is a value of Ua at which dispersion is minimal, and (iv) that for extremely large values of Ua the diffusion model of Part I breaks down as predicted.

1.10 ROSE, D. A. (1971) Water movement in dry soils: II. An analysis of hysteresis. *Journal of Soil Science* **22**, 490–507.

The hysteresis that occurs in the micro-hydrological characteristics of a soil (conductivity and diffusivity) as functions of water content and water potential between sorption and desorption is examined for three soils (sand, loam and clay) and sepiolite. These materials, all aggregated, are sufficiently dry that both the vapour and liquid components of water movement are important.

At any water content or water potential the vapour conductivity is always bigger when wetting than when drying though differences may be small.

There is hysteresis in water (vapour + liquid) conductivity as a function of *water content* when vapour flow is dominant but not when liquid flow is dominant. Conversely, there is hysteresis in water conductivity as a function of *water potential* when liquid flow but not vapour flow is dominant. Both forms of this hysteresis are small.

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Hysteresis in diffusivity exists as a function of both water content and water potential, but is complicated.

Variations caused by hysteresis are probably negligible in practice, swamped by effects caused by changes in the soil environment (e.g. temperature) or by changes in soil management (e.g. structure).

1.11 ROSE, D. A. & (PASSIOURA, J. B.) (1971) The analysis of experiments on hydrodynamic dispersion. *Soil Science* **111**, 252–257.

An objective method of analyzing experiments on hydrodynamic dispersion is based on the logarithmic–normal transformation of a numerical solution of the equation of longitudinal dispersion in a finite column. Experimental values that satisfy the conditions of the analysis fall on a straight line when transformed, the slope of which is a unique function of Brenner number. Several conditions that cause deviations from a straight line are illustrated.

1.12 ROSE, D. A. & (PASSIOURA, J. B.) (1971) Gravity segregation during miscible displacement experiments. *Soil Science* **111**, 258–265.

When the liquid resident in a horizontal bed of porous material is displaced by another liquid of different density, the resulting dispersion of solute is enhanced by the formation of a tongue of denser liquid undershooting the lighter liquid. This phenomenon of gravity segregation is responsible for many anomalous results in the literature on hydrodynamic dispersion of solutes.

The size of the gravity segregation effect depends directly on (i) the permeability of the bed, (ii) the difference in density between the two liquids, (iii) the thickness of the bed over which this density difference operates, and, inversely, on (iv) the flow velocity, and (v) the length of the bed.

The main features of gravity segregation were illustrated in a series of miscible displacement experiments using two sizes of glass spheres (210–250 μm and 420–500 μm diameter), two flow velocities, and four density differences obtained from pairs of NaCl solutions and water. Increased dispersion of solute was noted with a density difference as small as 2×10^{-4} g cm^{-3}, corresponding to a concentration difference of 0·005*N* NaCl.

Chemistry Department

BOOK

2.1 COOKE, G. W. (1972) *Fertilising for maximum yield.* London: Crosby Lockwood Ltd. i–xxiv, 296 pp.

GENERAL PAPERS

2.2 BENZIAN, B. (1971) Seed and forest nursery experiments in tree nutrition. Isobutylidene diurea (IBDU) in forest nurseries. Soaking conifer seed in micronutrient solutions. *Report on Forest Research* (*London*) *1971*, pp. 124–126.

2.3 COOKE, G. W. (1971) Fertilisers and society. *Proceedings of the Fertiliser Society* No. 121, 48 pp.

2.4 COOKE, G. W. (1972) Soil fertility problems in cereal growing in temperate areas. *Proceedings of the Ninth Congress of the International Potash Institute 1970*, 123–133.

2.5 COOKE, G. W. (1971) Plant nutrient cycles. *Proceedings of the 7th Colloquium of the International Potash Institute 1969*, 75–95.

2.6 COOKE, G. W. (1971) Potassium for grassland. Present use and future possibilities In: *Potassium and systems of grassland farming.* The Potassium Institute Ltd., pp. 5–14.

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2.7 COOKE, G. W. (1971) Value and valuation of fertiliser residues. In: *Residual value of applied nutrients. Ministry of Agriculture, Fisheries and Food. Technical Bulletin No. 20.* London: H.M.S.O., pp. 296–317.

2.8 GASSER, J. K. R. (1971) Nature and value of residual fertiliser nitrogen in soil. In: *Residual value of applied nutrients*, pp. 114–124.

2.9 GASSER, J. K. R. (1971) Some biological effects of ammonia injected into soils. *Anhydrous ammonia. Proceedings of a symposium on aspects of its technology and use as a fertilizer.* National College of Agricultural Engineering, Silsoe, 15–17 December 1970. Guildford: IPC Science and Technology Press Ltd., pp. 30–38.

2.10 JOHNSTON, A. E. (1971) Potassium residues in soils from experiments at Rothamsted and Woburn. In: *Residual value of applied nutrients*, pp. 220–236.

2.11 MATTINGLY, G. E. G. (1971) Residual value of phosphate fertilisers on neutral and calcareous soils. In: *Residual value of applied nutrients*, pp. 1–15.

2.12 NOWAKOWSKI, T. Z. (1971) Potassium requirements of herbage in relation to nitrogen. In: *Potassium and systems of grassland farming*. The Potassium Institute Ltd., pp. 37–46.

PAPERS IN ROTHAMSTED REPORT, PART 2

2.13 COOKE, G. W. & WILLIAMS, R. J. B. (1972) Problems with cultivations and soil structure at Saxmundham. *Rothamsted Experimental Station. Report for 1971*, Part 2, 122–142.

Soil physical conditions, cropping and cultivation problems on a Chalky Boulder Clay in East Suffolk are discussed with reference to soil physical measurements and meteorological data.

2.14 JOHNSTON, A. E. & PENNY, A. (1972) The Agdell experiment, 1848–1970. *Rothamsted Experimental Station. Report for 1971*, Part 2, 38–68.

This paper estimates the soil P and K accumulated from fertilisers given between 1848 and 1951 and not removed in crops grown in the four-course rotation experiment; these estimates are related to 1953 analyses for soil P and K. Recoveries of the residues by grass grown between 1958 and 1970 are given and related to changes in soluble P and K in the soils. The effects of residues on the responses by grass to new dressings of P and K were also measured.

2.15 JOHNSTON, A. E. (1972) Changes in soil properties caused by the new liming scheme on Park Grass. *Rothamsted Experimental Station. Report for 1971*, Part 2, 177–180.

This paper states the amounts of chalk given so far to the new subplots *b* and *c* where soil acidity is to be lessened in the new liming scheme. The pH of the 'mats' and the mineral soil at three depths, 0 to 7·5, 7·5 to 15 and 15 to 22·5 cm at three sampling dates, November 1959, 1967 and 1971, are given to show the effect of the chalk. The apparent retention of large quantities of calcium in the partially decomposed vegetation of the mat is discussed.

2.16 WIDDOWSON, F. V. & PENNY, A. (1972) Results from the Woburn Reference experiment, 1960–69. *Rothamsted Experimental Station. Report for 1971*, Part 2, 69–94.

The effects of N, P, K and Mg fertilisers and of FYM on the yield of six crops and soft fruit are given and discussed. The amounts of N, P, K and Mg recovered by the crops from fertilisers, from FYM and from the soil are also given and from these a balance sheet for N, P and K constructed. The effects of the different manurings on crop yields and soil P and K status over ten years are shown and discussed.

2.17 WILLIAMS, R. J. B. & COOKE, G. W. (1972) Experiments on herbage crops at Saxmundham, 1967–71. *Rothamsted Experimental Station. Report for 1971*, Part 2, 95–121.

Yields, nutrient contents of grass, lucerne and red clover grown on a Chalky Boulder Clay in East Suffolk are related to soil analyses and to fertiliser responses. The effects of time of fertilizer

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application and frequency of cutting upon crop composition, (particularly N and Mg contents) and the yield of dry matter per unit of rain are discussed.

Research Papers

2.18 Addiscott, T. M. & Johnston, A. E. (1971) Potassium in soils under different cropping systems. 2. The effects of cropping systems on the retention by the soils of added K not used by crops. *Journal of Agricultural Science* (*Cambridge*) **76**, 553–561.

The K balance, the difference between K added as fertiliser or farmyard manure (FYM) and K removed by the crops, was calculated for soils from the Classical and Ley–Arable experiments at Rothamsted and for the Woburn Ley–Arable experiment, for the duration of each experiment. Linear regressions on K balance accounted for 78% of the variation in exchangeable K (K_e) and for 83% in K uptake by ryegrass (K_p) in the Classical experiments, for 56 and 60% respectively in the Ley–Arable experiments at Rothamsted, and for 39 and 6% in the Woburn Ley–Arable experiment.

Regressions of K_e and K_p on K balance suggested that, in the Rothamsted Ley–Arable experiments, rather more than half of the K balance remained extractable by ryegrass from the plots with a rotation of crops, and apparently all the K balance from those under continuous grass. About one-fifth of the K balance remained extractable by ryegrass from the soils in the Rothamsted Classical experiments and soils given FYM retained K slightly better than other soils. With all soils about half the K extractable by ryegrass was exchangeable to ammonium acetate.

The plots with FYM or under continuous grass contain more organic matter than other plots in the same experiments. The following possible effects of increasing the organic matter content of the soils were investigated by calculating the multiple regressions of K_e and K_p on K balance with either percentage of organic C, total CEC, or organic CEC: (1) loss of K decreased by increasing the water retention and lessening leaching; (2) improved K retention by increasing the total cation exchange capacity (CEC) available for K absorption; (3) improved K retention by a mechanism arising from the different selectivities of clay and organic matter for K relative to Ca.

In the Classical experiments, where organic matter usually increases because of FYM additions, effect (2) seems the most probable, perhaps because the K given in the FYM was already absorbed by organic exchange sites. In the Ley–Arable experiments, where the K was given mainly as soluble K fertiliser and the organic matter develops mainly under grass, effects (1) or (3) seemed to operate, probably simultaneously.

The Woburn Ley–Arable experiment had no continuous grass plots, the soils differed little in organic matter content and no deductions could be made.

2.19 Addiscott, T. M. & Talibudeen, O. (1971) The transport of potassium to ryegrass roots in soils with and without added potassium. *Journal of Agricultural Science* (*Cambridge*) **76**, 411–418.

The mechanisms responsible for moving K from soil to root were studied by growing perennial ryegrass in pots containing a flinty silt loam from Rothamsted and a sandy Woburn soil, with and without added K, at 0·75 water-holding capacity. More water was taken up from the Rothamsted soil than from the Woburn soil, and less was taken up when K was added without affecting dry-matter production. After 25, 52, 83, 122, 194 and 276 days, K uptake, water uptake and the K concentration in the soil solution were measured and the mass-flow contribution to K uptake calculated.

Without added K, mass-flow accounted for only about one-sixth of the K taken up from the Rothamsted soil and about one-third from the Woburn soil. Except at first, diffusion probably accounted for the remainder of uptake but was the rate-controlling step for uptake from the Woburn soil only. With added K, mass-flow became much more important relative to diffusion in both soils, and transported more than enough K to account for the measured K uptake. Root interception probably did not contribute to K uptake after the early part of the experiment, because the pots used were small.

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2.20 ASHWORTH, J. & (COLLER, B. A. W.) (1971) Transmission of substituent effects in polar reactions. Part 1. Field effects in ester hydrolysis. *Transactions of the Faraday Society* **67**, 1069–1076.

Rate coefficients and Arrhenius activation parameters for the aqueous alkaline hydrolysis of esters X-CH_2OOEt have been measured. The changes, relative to when X is H, caused by charged or dipolar substituents are explicable in terms of direct electrostatic interaction, between X and the negative charge in the transition state, governed by an intramolecular dielectric permittivity.

2.21 ASHWORTH, J. & (COLLER, B. A. W.) (1971) Transmission of substituent effects in polar reactions. Part 2. Relative rates of halide displacement and ester saponification in the alkaline hydrolysis of α-haloacetate esters. *Transactions of the Faraday Society* **67**, 1077–1085.

Rate coefficients and activation energies for ester saponification in the alkaline hydrolysis of the ethyl esters of the α-haloacetic acids in aqueous solution have been determined by a pH-stat method with correction for the significant competition by displacement of halide ion for the bromo- and iodo-esters. While the gross effects of the halogens relative to hydrogen may be understood by reference to the influence of direct electrostatic fields, there is evidence that the rates of ester saponification may also be enhanced by partial displacement of the halide ion in the transition state. The dissociation of methane sulphonyloxyacetic acid and the kinetics of alkaline hydrolysis of its ethyl ester have been studied in the light of this hypothesis.

2.22 BENZIAN, B., FREEMAN, S. C. R. & MITCHELL, J. D. D. (1971) Isobutylidene diurea and other nitrogen fertilizers for seedlings and transplants of *Picea sitchensis* in two English forest nurseries. *Plant and Soil* **35**, 517–532.

Three slow-release nitrogen fertilisers—medium- and coarse-sized granules of IBDU (isobutylidene diurea) and formalised casein—were applied before sowing or transplanting to Sitka spruce *Picea sitchensis*, and their effects on growth compared with that on plots not given N or given four topdressings of 'Nitro-Chalk' (the source of N used in practice). The comparisons were made at two sites: a very sandy podsol and a sandy loam with better nutrient retention. The experiments with seedlings were continued for four years, those with transplants for three, and the same treatments were applied to the same plots each year.

Responses to 'Nitro-Chalk' were large, especially during wet seasons. Formalised casein was always as effective as 'Nitro-Chalk' for transplants. IBDU (especially the coarse fraction) was almost as good as formalised casein for transplants at both sites and equalled it for seedlings on the sandy loam. For seedlings on the sandy podsol, both particle sizes of IBDU became steadily less effective in succeeding years, and no satisfactory reason can be offered for this decline.

2.23 BOLTON, J. (1971) Controlling soil pH with different N fertilisers in experiments with ryegrass in pots. *Journal of Agricultural Science (Cambridge)* **77**, 549–551.

The pH of soil cropped with ryegrass increased with calcium nitrate as a fertiliser and decreased with ammonium nitrate, especially in the mid-range of pH. Changes above pH 7·2 and below pH 4·5 were small.

Yields of four cuts of grass given either N-fertiliser were similar over a pH range (in 0·01*M* $CaCl_2$) from 4·3 to 7·4. However, the composition of the grass and nutrient uptakes were affected by both soil pH and form of N fertiliser.

2.24 BOLTON, J. (1971) The chloride balance in a fertiliser experiment on sandy soil. *Journal of the Science of Food and Agriculture* **22**, 292–294.

One-third of the chloride, given as sodium chloride to kale and barley in successive years, was recovered in the harvested crops, or in ryegrass grown the following year. Crops on ground not given salt removed amounts of chloride comparable with those in the annual rainfall, so drainage losses under these crops were small.

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Improved analytical methods for chloride in soils and plants are described, using colorimetry and potentiometric titrations.

2.25 BOLTON, J. (1971) Quantity-intensity relationships for labile sodium in field soils. *Journal of Soil Science* **22**, 417–429.

Exchange isotherms for Na with Ca + Mg in ten unfertilised soils show smaller buffer capacities for Na than K, larger Na than K activity ratios at equilibrium, and curvatures of the graphs at small Na activity ratios that could indicate larger exchange energies on about 0·5% of the exchange sites.

Equilibrium Na activity ratios in the soils were similar to those in rain, the latter ratios could be most important in controlling Na activity ratios in soils and the percentage saturation of exchange complex with Na. The geochemical significance of these ratios is discussed.

2.26 BOLTON, J. & SLOPE, D. B. (1971) Effects of magnesium on cereals, potatoes and leys grown on the 'continuous cereals' site at Woburn. *Journal of Agricultural Science (Cambridge)* **77**, 253–259.

Symptoms of magnesium deficiency and take-all disease occurred during 1967 in wheat grown for the second year in succession on the Classical cereal site at Woburn. Magnesium fertilisers, which cured the deficiency symptoms and increased wheat yields in 1968 and 1969, had no effect on take-all. Leaves from crops severely attacked by take-all contained less nitrogen and potassium than leaves from unattacked plants but not less magnesium. In 1969 magnesium fertiliser did not increase yields or affect take-all of spring barley on the site but, in contrast to 1968, increased potato yields. Magnesium fertiliser improved the establishment of clover, especially on soil containing least magnesium.

Soil analyses show a tenfold decline in exchangeable Mg since 1888. Losses were most from soil given ammonium sulphate and more from the site where wheat was long grown than where barley was. Differences in soil magnesium did not explain large differences in yields of potatoes or leys between blocks of the experiments.

2.27 BRIGGS, G. G. & OGILVIE, S. Y. (1971) Metabolism of 3-chloro-4-methoxyaniline and some *N*-acyl derivatives in soil. *Pesticide Science* **2**, 165–168.

3-Chloro-4-methoxyaniline at concentrations of 10 ppm or more in soil is converted to a mixture of 3,3′dichloro-4,4′-dimethoxyazobenzene, 3-chlorobenzoquinone-4-(3-chloro-4-methoxyl)anil and its reduction product 2,3′-dichloro-4-hydroxy-4′-methoxydiphenylamine, probably by a free radical mechanism.

The herbicide metoxuron, and its demethylated metabolites probably break down to the amine too slowly in soil for coupling products to be detected. 3-Chloro-4-methoxyacetanilide at 25 ppm rapidly gives rise to amine coupling products in soil slurries and ethyl *N*-(3-chloro-4-methoxyphenyl)carbamate does so after two months in the slurries.

2.28 JENKINSON, D. S., NOWAKOWSKI, T. Z. & MITCHELL, J. D. D. (1972) Growth and uptake of nitrogen by wheat and ryegrass in fumigated and irradiated soil. *Plant and Soil* **36**, 149–158.

(For summary see No. 3.8.)

2.29 JOHNSTON, A. E. (1971) The effect of ley and arable systems of farming on soil potassium reserves. In: *Potassium and Systems of Grassland Farming*, The Potassium Institute Ltd., No. 1, 135–139.

Results from the Rothamsted Ley–Arable experiments during the years 1952–57 were given to show how the K manuring of three year sequences of grass leys used in various ways, of lucerne and of arable crops affected the readily soluble K reserves in soils, and the response of potatoes to extra fertiliser K. During the following years response by potatoes to extra K was used to show how the depletion of soil K reserves could be corrected by applying large dressings of fertiliser K and then prevented by increasing the K manuring to the ley and arable crops.

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2.30 JOHNSTON, A. E. & ADDISCOTT, T. M. (1971) Potassium in soils under different cropping systems. 1. Behaviour of K remaining in soils from classical and rotation experiments at Rothamsted and Woburn and evaluation of methods of measuring soil potassium. *Journal of Agricultural Science* (*Cambridge*) **76**, 539–552.

Measurements made on soils from the Ley–Arable rotation experiments and some of the Classical experiments at Rothamsted and Woburn are described. Values of exchangeable K, equilibrium activity ratio, equilibrium K potential, and buffer capacity are given for each plot. Potassium quantity/intensity relationships measured for each plot showed that no differences in K exchange behaviour have arisen as a result of manuring or of ley or arable treatments. The only fundamental variation was in the quantity of K in the soils. Continuous ley plots, whether given N fertiliser or containing clover, contained much more K than plots carrying crop rotations. In the Classical experiment soils, quantity of K depended largely on manuring.

Potassium uptakes by ryegrass grown on the soils from the various plots are discussed. Potassium uptake was well related to quantity of K, better so than to the other K parameters. The release of non-exchangeable K to the crop was non-linearly related to the fall in exchangeable K in the soils from the Rothamsted Ley–Arable experiments.

Drying and re-wetting the cropped soils released K in amounts inversely proportional to the amount of K in the *moist* cropped soil. This release of K was unrelated to the original exchangeable K contents of the soils.

2.31 MATTINGLY, G. E. G., PENNY, A. & BLAKEMORE, M. (1971) Evaluation of phosphate fertilisers. III. Immediate and residual values of potassium metaphosphate and magnesium ammonium phosphate for potatoes, radishes, barley and ryegrass. *Journal of Agricultural Science* (*Cambridge*) **76**, 131–141.

Triple superphosphate (21·6% P), potassium metaphosphate (25·0% P) and magnesium ammonium phosphate (19·0% P) were compared as phosphate fertilisers alone and in combination, and as powders and granules, in two experiments on acid soils. Basal nutrients were adjusted to allow for the amounts of N, K and Mg in the test fertilisers. Immediate effects of the fertilisers were measured by early potatoes and barley, and residual effects by radishes and ryegrass.

All powdered fertilisers, alone or in combination, were equivalent to powdered superphosphate for early potatoes. The value of granular fertilisers for potatoes increased with the proportion of superphosphate in the mixtures. Superphosphate equivalents of the granular fertilisers were: magnesium ammonium phosphate, 14%; potassium metaphosphate + magnesium ammonium phosphate, 36%; potassium metaphosphate, 53%; superphosphate + potassium metaphosphate + magnesium ammonium phosphate, 54%; superphosphate + magnesium ammonium phosphate, 60%; superphosphate + potassium metaphosphate, 81%.

Residues from powdered fertilisers, applied to potatoes, were equivalent, for radishes, to residues from powdered superphosphate. Residues from granular fertilisers were more effective for radishes than residues from powders.

All powdered fertilisers were equivalent to powdered superphosphate for barley cut green. Granular magnesium ammonium phosphate, either alone or mixed with potassium metaphosphate, was slightly less effective than powder.

Residues from all powdered fertilisers applied to barley were equivalent for ryegrass. Residues from granular fertilisers, especially potassium metaphosphate and magnesium ammonium phosphate, produced more grass than residues from powders.

Apparent recoveries of P by the four crops ranged from 24% to 32% and were more from granules than from powders. Residues from all fertilisers increased 0·5*M* $NaHCO_3$-soluble P in soils, and mean yields of ryegrass, the final test crop, increased by 3·2 to 5·1 cwt dry matter/acre/ppm $NaHCO_3$-soluble P in the soils.

2.32 (SINGH, M. M.) & TALIBUDEEN, O. (1971) K-Al exchange equilibria in acid soils of Malaya and the use of thermodynamic functions to predict the release of non-exchangeable K in soil to plants. *Proceedings of the International Symposium on Soil Fertility Evaluation, New Delhi* **1**, 85–95.

A thermodynamic treatment of cation exchange equilibria was used to interpret K-Al exchange equilibria in 0·01*N* solutions for nine common acid soils of Malaya. In seven of the nine soils,

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K was adsorbed more strongly than Al while for the remaining two, the reverse was the case. The standard free energy for formation of K-soil from Al-soil varied from — 2550 to 900 calories/mole.

In all soils, the activity coefficient of the adsorbed K ions, f_K, first increased and then decreased with decreasing K-saturation, while f_{Al}, the activity coefficient of the adsorbed Al ions, decreased continuously with decreasing Al-saturation. Between soils, changes in f_K with K saturation varied much more than changes in f_{Al}. Excess free energy functions for Al→K exchange calculated from (f_K, f_{Al}) values for the soils showed distinct differences between all soils. For soils containing micaceous minerals, these differences in the surface chemistry of the soils were related to the release of initially non-exchangeable potassium in the soil to *Pueraria phaseoloides* in glasshouse experiments.

2.33 SIVASUBRAMANIAM, S. & TALIBUDEEN, O. (1971) Effect of aluminium on growth of tea (*Camellia sinensis*) and its uptake of potassium and phosphorus. *Journal of the Science of Food and Agriculture* **22**, 325–329.

Tea seedlings were grown for up to 10 months in the glasshouse in an acid soil, to which solutions of varying K/Al concentration ratios were given weekly. During growth, the %K in the leaf dry matter increased with the labile K concentration but was not influenced by the Al concentration in the soil. However, the largest level of Al in soil decreased plant growth and %K in the dry matter. At this level of Al in soil, plant height, number of leaves, dry matter and %K in the dry matter increased linearly with the K given to the soil. The %Al in the plant was not affected by the labile K and Al contents of the soil.

A highly significant linear relationship was observed between Al and P uptake by parts of the plant and by the whole plant, even though the soil was not treated with P as a basal nutrient. The Al/P ratios in the first mature leaf, total leaves and stems were 3·4, 3·0 and 0·8, respectively, after six months growth. Uptake mechanisms are proposed to explain this.

2.34 SIVASUBRAMANIAM, S. & TALIBUDEEN, O. (1972) Potassium : aluminium exchange in acid soils. Part 1. Kinetics. *Journal of Soil Science* **23**. (In the press.)

A kinetic method is described and investigated for determining exchangeable Al in acid soils using *M* NH_4Cl solutions whose pH and leaching rate were critical for obtaining accurate and reproducible values. Molar concentrations of ammonium acetate displaced at least part of the Al chelated to functional groups in the soil organic matter.

The adsorption kinetics of K and Al from $10^{-3}M$ chloride solutions on the NH_4-saturated forms (at the soil pH) of these soils, under leaching conditions similar to the 'extraction' method, showed that, when the atom ratio K : Al > 1 in the equilibriating solution, initially more K was adsorbed than at equilibrium, although Al did not 'over-equilibriate' when K : Al < 1. At least 24 hours were required for attaining equilibrium in K : Al equilibria work with soils and clays.

The kinetics of desorption (extraction method) and adsorption of K and Al obeyed the first-order and parabolic rate respectively. This is attributed to the large difference in anion concentrations in the two methods.

2.35 (SOONG, N. K., PUSHPARAJAH, E., SINGH, M. M.) & TALIBUDEEN, O. (1971) Determination of active root distribution of *Hevea brasiliensis* using radioactive phosphorus. *Proceedings of the International Symposium on Soil Fertility Evaluation, New Delhi* **1**, 309–315.

Phosphorus uptake by *Hevea* seedlings from nutrient solution and by mature *Hevea* trees from the soil was studied using ^{32}P tracer. The usefulness of leaves and latex for detecting ^{32}P uptake by *Hevea* was compared. Latex assay was found to be more convenient and reliable than leaf assay and was used to determine the relative distribution of active roots of *Hevea* in three different soil zones under study. Maximum root activity was found to be in the first 12 ft from the trees, reflecting past cultural practices.

Injection of ^{32}P into the trunk of a mature rubber tree showed translocation into the leaves

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and latex but no radioactivity could be detected in the roots or in the surrounding soil indicating that trunk injection was unsuitable for estimating the distribution of active roots in soil.

2.36 TALIBUDEEN, O. (1971) The fertility status of soil potassium related to K : Ca exchange isotherms from 'double-label' experiments. *Proceedings of the International Symposium on Soil Fertility Evaluation, New Delhi* **1**, 97–103.

The potassium fertility status of soils is defined by the 'exchangeable' and 'non-exchangeable' K they release to crops. Soils containing significant amounts of K-bearing minerals release various amounts of K from these two fractions.

Thermodynamic functions derived from the K : Ca exchange isotherms of 10 English soils (in 'double-label' experiments) are examined to elucidate the changes in the adsorbed ion layer at the surface. Transitions in the activity coefficient of adsorbed K, f_K, and the excess enthalpy with increasing K saturation, N_K, suggest the presence of minerals or groups of exchange sites of different K specificity. Changes in f_K and the excess free energy at $N_K \rightarrow O$ seem to predict reliably the ability of the soil to release non-exchangeable K to ryegrass.

2.37 WIDDOWSON, F. V. & PENNY, A. (1971) Anhydrous ammonia—yields and recoveries by spring wheat. *Anhydrous ammonia. Proceedings of a symposium on aspects of its technology and use as a fertilizer.* National College of Agricultural Engineering, Silsoe, 15–17 December 1970. Guildford: IPC Science and Technology Press Ltd., pp. 61–66.

From 1966 to 1968 five experiments were done with spring wheat; three were on clay loams overlying Clay-with-Flints at Rothamsted, Hertfordshire, and two on sandy loams overlying Lower Greensand at Woburn, Bedfordshire. In each, anhydrous ammonia (82% N) was injected in bands 12 in. apart and 4–5 in. deep along 100 ft plots, with a tractor applicator set to give 0·5, 1·0 and 1·5 cwt N/acre. The amount used was either weighed or measured and then equivalent amounts of ammonium nitrate ('Nitro-Chalk 21') were broadcast by hand and the seed sown.

The efficiency of the anhydrous ammonia relative to ammonium nitrate was assessed first at ear emergence (in late June) and secondly at harvest, by measuring yields of dry matter and its N per cent. At ear emergence, yields, N percentages and apparent N recoveries were much larger from ammonium nitrate than from anhydrous ammonia. At harvest, differences were smaller, but ammonium nitrate gave the larger grain yields especially with the two smaller amounts of N, and the wheat recovered more N from it.

Thus, anhydrous ammonia seemed less efficient than ammonium nitrate, and when used for spring wheat more N than usual will be needed to obtain a given yield.

Pedology Department

GENERAL PAPER

3.1 BLOOMFIELD, C. (1970) The mechanism of podzolisation. In: 'Soil Heterogeneity and Podzolisation'. *Welsh Soils Discussion Group, Report* No. 11, 112–123.

PAPER IN ROTHAMSTED REPORT, PART 2

3.2 AVERY, B. W., BULLOCK, P., CATT, J. A., NEWMAN, A. C. D., RAYNER, J. H. & WEIR, A. H. (1972) The soil of Barnfield. *Rothamsted Experimental Station. Report for 1971*, Part 2, 5–37.

RESEARCH PAPERS

3.3 BLOOMFIELD, C. (1972) The oxidation of iron sulphides in soils in relation to the formation of acid sulphate soils, and of ochre deposits in field drains. *Journal of Soil Science* **23**, 1–16.

Aerating pyritic soils causes acidification and the formation of acid sulphate soils, or cat-clay. The oxidation of pyrite in soils is associated with the deposition in drains of a form of ochre

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quite distinct from that formed by the action of filamentous iron bacteria. Pyrite-derived ochre results from the action of *Thiobacillus ferrooxidans*, which, below pH 3·5–4·0, catalyses the oxidation of Fe^{2+} and pyrite. In soils less acid than *c.* 4, pyrite oxidises relatively slowly by chemical reactions to Fe^{2+} and SO_4^{2-}. Under these conditions iron enters the drains as Fe^{2+} and is there oxidised by *T. ferrooxidans* and deposited as hydrated ferric oxide. Once the soil becomes acid enough for *T. ferrooxidans* to multiply, the rate at which pyrite oxidises increases several-fold, and at *c.* pH 3 iron appears in the drainage water in the ferric form. Liming decreases the rate at which pyrite is oxidised.

3.4 BROWN, G., CALLOW, R. K., GREEN, C. D., JONES, F. G. W., RAYNER, J. H., SHEPHERD, A. M. & WILLIAMS, T. D. (1971) The structure, composition, and origin of the sub-crystalline layer in some species of the genus *Heterodera*. *Nematologica* **17**, 591–599.

(For summary see No. 8.5.)

3.5 BROWN, G. & JENKINSON, D. S. (1971) Bromine in wheat grown on soil fumigated with methyl bromide. *Soil Science and Plant Analysis* **2**, 45–54.

Patches of discoloured ('scorched') plants developed in winter wheat in a field that had been fumigated with methyl bromide. Scorching was greatest round sites where the methyl bromide was injected and was associated with the uptake of bromine by the plants. The above-ground parts of the scorched plants contained up to 0·61% bromine. In one scorched area, the first, second and third wheat crops after fumigation contained 0·42, 0·25 and 0·09% bromine respectively, so that in three years not all the residual bromine had leached from the soil.

The greater the organic content of a soil, the more bromine remained after fumigation with methyl bromide; a soil with 2·81% organic carbon contained 63 ppm bromine after fumigation in the laboratory, and an otherwise similar soil, with 0·93% organic carbon, contained 25 ppm. The residual bromine from methyl bromide fumigation could be extracted with N potassium sulphate, whereas the native soil bromine could not.

3.6 CATT, J. A., CORBETT, W. M., HODGE, C. A. H., MADGETT, P. A., TATLER, W. & WEIR, A. H. (1971) Loess in the soils of north Norfolk. *Journal of Soil Science* **22**, 444–452.

Thin silty deposits cover large areas of north-east Norfolk, occurring mainly on gently sloping and flat plateau sites and on the floors of valleys cut in the glacial deposits. The particle size and geographic distribution of the deposits suggest that the silt is windblown. The mineralogical composition of the silt fraction resembles that of the silt of the Hunstanton Till, suggesting that most of the deposit was derived as loess from outwash of the Weichselian glacier. However, at some localities the sand and clay components of the deposits were at least partly derived from subjacent glacial sediments of pre-Weichselian age. The distribution of the silty deposits strongly affects the pattern of soil types, and sometimes the growth of crops.

3.7 CATT, J. A., (GAD, M. A.), LE RICHE, H. H. (& LORD, A. R.) (1971) Geochemistry, micropalaeontology and origin of the Middle Lias ironstones in north-east Yorkshire (Great Britain). *Chemical Geology* **8**, 61–76.

The chemical and mineralogical composition of chamosite-siderite ironstones and less ferruginous sandy shales in the Middle Lias succession of north-east Yorkshire are described. The iron was probably derived from soils formed by acid weathering of Palaeozoic sediments on a well-vegetated Pennine land area. It moved mainly as oxide, but local mildly reducing conditions during early diagenesis mobilised part of the oxide, so that chamosite was formed, and locally some pyrites also. The microfauna (benthonic ostracods and Foraminifera) was discouraged by some feature of the bottom conditions, possibly the concentration of minor elements derived from the acid soils. The abundant siderite formed in later diagenesis probably originated by mutual oxidation-reduction of organic matter and the remaining iron oxide. Sulphur, zinc, lead and other trace elements associated with the organic matter were then released, and segregated as accessory sphalerite, galena, etc.

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3.8 JENKINSON, D. S., NOWAKOWSKI, T. Z. & MITCHELL, J. D. D. (1972) Growth and uptake of nitrogen by wheat and ryegrass in fumigated and irradiated soil. *Plant and Soil* **36**, 149–158.)

Wheat and ryegrass were grown in pots containing soil that had been irradiated, fumigated with methyl bromide, fumigated with formaldehyde, or left untreated. All pots received a basal dressing of potassium, phosphorus and magnesium; the response to nitrogen was tested by applying 0, 0·177 or 0·354 g nitrogen per pot. Irradiation increased the growth of wheat and ryegrass, and their uptake of nitrogen. The amount of fertiliser nitrogen equivalent to the nitrogen supplied by seeds and soil (the 'N value') can be calculated from the efficiency of uptake of fertiliser released by irradiated soil. With wheat the increase in growth can be attributed solely to the extra mineral nitrogen released by irradiated soil. However, ryegrass grew a little better than would have been expected had the only effect of irradiation been to increase the release of soil nitrogen.

Fumigation with methyl bromide or formaldehyde increased the growth of wheat and ryegrass not given fertiliser nitrogen. However, fumigation with methyl bromide left ionic bromide in the soil, and this depressed the growth of wheat given fertiliser nitrogen. Formaldehyde also left residues; these influenced soil metabolism and sometimes depressed the growth of plants given fertiliser nitrogen.

3.9 KING, H. G. C. & PRUDEN, G. (1971) The spectrophotometric determination of the purity of commercial dithizone and the purification of small quantities of the reagent by chromatography. *Analyst* (*London*) **96**, 146–148.

The purity of commercial dithizone is determined quantitatively by comparing the optical density of a solution at wavelength 620 nm with that of a pure sample. Qualitatively, the purity is estimated from the pattern obtained by chromatographing the crude dithizone on Whatman SG81 (silica-impregnated) paper. Small amounts of the pure reagent are separated by chromatography on large sheets of Whatman SG81 paper or on a column consisting of a mixture of equal parts of acid-washed silica gel (Kieselgel N) and Celite 545 with benzene as eluting agent.

3.10 KRZANOWSKI, W. J., & NEWMAN, A. C. D. (1972) A computer simulation of cation distribution in the octahedral layers of micas. *Mineralogical Magazine*. (In the press.)

(For summary see No. 12.10.)

3.11 (THOREZ, J.), BULLOCK, P., CATT, J. A. & WEIR, A. H. (1971) The petrography and origin of deposits filling solution pipes in the Chalk near South Mimms, Hertfordshire. *Geological Magazine* **108**, 413–423.

Pipes and other solution cavities in the Upper Chalk near South Mimms contain deposits contrasting with those in similar situations elsewhere in Great Britain. The cavities were formed near the sub-Palaeogene surface, and most of the deposits in them were derived from the basal Palaeogene beds (Thanetian and Sparnacian). A dark brown and very porous clay, which lines many of the pipes, is composed partly of the insoluble residue from the Chalk and partly of clay eluviated from the Palaeogene deposits. The clay was deposited from percolating water in spaces formed by dissolution of chalk at the margins of the pipes.

3.12 WILLIAMS, C. & BROWN, G. (1971) Uranium content of peaty soils rich in molybdenum and selenium from Co. Limerick, Eire. *Geoderma* **6**, 223–225.

Peaty soils from Kilcolman, Co. Limerick, previously shown to contain anomalously large amounts of selenium and molybdenum, contain up to 550 ppm uranium and 150 ppm bromine. The uranium probably derives from the Clare Shales and has probably been concentrated on the peat from drainage waters.

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Soil Microbiology Department

Thesis

4.1 Bonish, P. (1971) The possible role of some enzymes degrading plant cell wall substances in the infection of clover by nodule bacteria. Ph.D. Thesis, University of London.

General Papers

4.2 Dart, P. J., Day, J. M. & Harris, D. (1972) Assay of nitrogenase activity by acetylene reduction. *IAEA/FAO Grain Legume Panel, Technical Booklet.* (In the press.)

4.3 Döbereiner, J., Day, J. M. & Dart, P. J. (1972) Rhizosphere associations between grasses and nitrogen-fixing bacteria: effect of oxygen tension on nitrogenase activity in the rhizosphere of *Paspalum notatum*. *Soil Biology and Biochemistry.* (In the press.)

4.4 Döbereiner, J., Day, J. M. & Dart, P. J. (1972) Fixacao de nitrogenio na rhizosfera de *Paspalum notatum* e da cana de acucar. *Pesquisa. Agropecuária Brasileira.* (In the press.)

4.5 Hayman, D. S. (1972) Microbiology of the soil. *Report on the Progress of Applied Chemistry.* (In the press.)

4.6 Nutman, P. S. (1972) The influence of physical environmental factors on the activity of *Rhizobium* in soil and in symbiosis. *IAEA/FAO Grain legume Panel, Technical Booklet.* (In the press.)

Research Papers

4.7 Döbereiner, J., Day, J. M. & Dart, P. J. (1972) Nitrogenase activity of the *Paspalum notatum-Azotobacter paspali* association and oxygen sensitivity. *Journal of General Microbiology* **71**, 103–116.

Nitrogenase activity in the rhizosphere of a grass, *Paspalum notatum* and its associated soil was measured by the reduction of acetylene. Roots of the cultivar 'batatais' colonised by *Azotobacter paspali*, when taken from the soil, produced 1 to 32 μmoles C_2H_4/g dry weight/h, whereas the cultivar 'pensacola', which is not colonised by *A. paspali*, produced less than 0·5 μmoles g/h. There was a lag of 12 to 24 hours before maximum, linear rates of acetylene reduction were reached. Activity was greatest at around pO_2 0·04 atm. Activity of soil cores containing plants with leaves attached was little affected by pO_2 and showed no lag. Soil-plant cores maintained in a 16 hour day–8 hour night showed no diurnal fluctuation in activity; as the dark period was extended, activity decreased but was restored on returning plants to the light. Roots and rhizomes had most activity, the soil very little and aerial parts none. Washing the roots removed less than half the activity. Disturbance of soil–plant cores decreased activity. The soil next to the root surface contained most *A. paspali*; more were associated with active plants than with less active plants. Sections of roots showed abundant bacteria adjacent to the root surface. Nitrogen fixation by the association was estimated to be up to 90 kg N/ha/annum.

4.8 Döbereiner, J. Day, J. M. & Dart, P. J. (1972) Nitrogenase activity in the rhizosphere of sugar cane and some other tropical grasses. *Plant and Soil* **37**. (In the press.)

Roots of sugar cane had considerable nitrogenase activity and produced up to 5 n*M* ethylene/h/g root by the reduction of acetylene. The rhizosphere soil and soil mid-way between the cane rows also reduced acetylene. *Beijerinckia indica* was abundant on roots and in the soil. Nitrogenase activity was also associated with roots of *Panicum maximum*, *Pennisetum purpureum* and *Cynbopogon citratus*.

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4.9 HAYMAN, D. S. & MOSSE, B. (1972) Plant growth responses to vesicular-arbuscular mycorrhiza. III. Increased uptake of labile P from soil. *New Phytologist* **71**, 41–47.

Onion plants were grown in a range of soils labelled with ^{32}P. It was found that although the mycorrhizal plants had taken up more phosphorus and grown larger, the proportion of ^{32}P to total P (specific activity) taken up by mycorrhizal and non-mycorrhizal plants after 10 weeks was not significantly different. It is concluded that the mycorrhizal roots used the same source of labile phosphate but explored a greater volume of soil beyond the zone of phosphate depletion near the root surface. There was no indication that mycorrhizal roots had access to sources of phosphate different from those accessible to non-mycorrhizal roots.

The specific activity of $NaHCO_3$-extractable phosphorus differed considerably between the eight soils but the specific activity of absorbed phosphorus in the plants always corresponded closely to that of the soil in which they had grown.

4.10 HEPPER, C. M. (1972) Composition of extracellular polysaccharides of *Rhizobium trifolii*. *Antonie van Leeuwenhoek*. (In the press.)

Analysis of the extracellular polysaccharides of some related strains of *Rhziobium trifolii* indicates the presence of glucose, galactose, glucuronic acid, pyruvate and acetate. Small differences in composition between strains were not related to the nodulating ability or capacity to fix nitrogen with clover.

4.11 KLECZKOWSKA, J. (1972) Establishment of phage and bacteria in sterilised compost in a glasshouse. *Plant and Soil*. (In the press.)

Four strains of *Rhizobium trifolii* were individually inoculated to pots containing sterilised sand-vermiculite mixture, half of which were seeded with red clover and half not.

Pots were maintained in an ordinary glasshouse and watered with tap water.

Phage was first detected after four months and almost all pots contained one or more phages against *Rhizobium trifolii* after nine months. The presence of plants increased the titre of phages in some pots inoculated with *R. trifolii* but had no effect on the number of different phages.

The pots also contained phages against soil bacteria other than *Rhizobium* indicating that phages are readily spread and constitute a part of the life cycle of soil bacteria.

The number of different phages isolated from the pots was affected by the strain of *Rhizobium* used as inoculum.

4.12 MOSSE, B. & PHILLIPS, J. M. (1971) The influence of phosphate and other nutrients on the development of vesicular-arbuscular mycorrhiza in culture. *Journal of General Microbiology* **69**, 157–166.

Vesicular-arbuscular mycorrhiza were established in *Trifolium parviflorum* in culture by inoculation with *Endogone* spores. In a medium containing 265 mg P/l, as $CaHPO_4$ and K_2HPO_4, infection occurred only when the medium lacked N. In a medium containing only 100 mg P/l, infection occurred readily in the presence of 0·5 g KNO_3/l.

Calcium monohydrogen phosphate, Ca phytate, Na phytate, Fe phytate, phytin, lecithin and DNA were adequate sources of phosphate for both plant and fungus. Ca phytate and DNA greatly stimulated fungal growth, and DNA also stimulated spore formation, in the agar medium. With Na in the medium infections in the root were sparse. Inositol may serve as a carbon source for *Endogone*.

Mycorrhizal infection occurred with either $FeCl_3$ or Fe-EDTA in the medium; when so little iron was present that plants grew poorly, there was also little mycorrhizal infection.

Botany Department

GENERAL PAPERS

5.1 THORNE, G. N. (1971) Controlled environments for plant growth. *Laboratory Practice* **20**, 719–720 and 724.

5.2 WHITTINGHAM, C. P. (1972) The relationship between crop physiology and analytical plant physiology. *Glasshouse Crops Research Institute Symposium*. (In the press.)

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Research Papers

5.3 Bird, I. F., Keys, A. J. & Whittingham, C. P. (1972) Intercellular location of enzymes of the glycollate pathway. *Proceedings of the Second International Conference on Photosynthesis (Italy, 1971).* (In the press.)

Freeze dried powders prepared from leaves of *Nicotiana tabacum* var. White Burley were ground in a mortar with or without milling and the chloroplasts separated using non-aqueous solvents. There was no significant loss in enzyme activity during the fractionation procedure. There was more glycollic oxidase and glycerate dehydrogenase outside than inside the chloroplasts. Using the activity of pyruvate kinase as a measure of the degree of contamination of the chloroplast fraction by non-chloroplast material, an upper estimate of contamination of 30% was calculated. When the ball-milling procedure was omitted, the enzymes concerned in the glycollate pathway appeared to a greater extent in the chloroplast fraction. Serine-glyoxylate transaminase of slight activity was distributed similarly to glycollate oxidase and glycerate dehydrogenase, consistent with all three enzymes being localised in the peroxisomes. A decarboxylation with a concomitant synthesis of serine observed both with fresh leaves and with crude homogenates was catalysed by a different enzyme system. The reaction was not significantly stimulated by adding tetrahydrofolate or NAD. The decarboxylase activity was increased with increased oxygen partial pressure and during the reaction oxygen was taken up; it was inhibited by various compounds known to inhibit mitochondrial processes and it is suggested that the enzyme system responsible is probably located in the mitochondria. Non-green or etiolated plant tissue showed relatively little activity.

5.4 (Dyson, P. W.) & Watson, D. J. (1971) An analysis of the effects of nutrient supply on the growth of potato crops. *Annals of Applied Biology* **69**, 47–63.

Fertiliser nitrogen did not delay tuber initiation by the potato variety King Edward in the field, but slowed the early growth of tubers. Later, N hastened tuber growth and the largest amounts prolonged it. Leaf and stem growth were increased by N from an early stage. Leaf area index (L) reached maxima of 2·5 to 3·0 with the largest amounts of N, and 1·0 with no nitrogen: L decreased after late July, faster with increased N, and only the largest amount prolonged the life of the haulm. N increased leaf area duration (D) by up to 125% in both years. D was 21% greater in 1964 than 1963, and net assimilation rate in August and September was larger; consequently mean yield was 50% more in 1964. Uptake of nitrogen and N% of dry matter were increased by increasing nitrogen. The N% of tuber dry weight remained constant or increased slightly from about two weeks after tuber formation, while N% of the leaves and stems decreased rapidly, and much N was transferred from tops to tubers. The 1964 results suggest that tuber growth depends on continued nitrogen uptake by the plant.

P and K had small effects compared with those of N. K increased leaf area duration by 9% in 1963 and 3% in 1964, and yield by 11 and 8% respectively. P increased leaf area duration by 17% and yield by 9% in 1964. K had very small effects until the end of the season, when it prolonged the period of growth. P increased growth rates of all parts of the plant up to four weeks from emergence, and the differences in dry weight at that time persisted to maturity but did not increase.

5.5 Spence, J. A. & Humphries, E. C. (1972) Effect of moisture supply, root temperature and growth regulators on photosynthesis of isolated rooted leaves of sweet potato (*Ipomoea batatus*). *Annals of Botany* **36**, 115–121 .

Isolated rooted sweet potato leaves were used to study the effect of carbohydrate and storage on photosynthesis. Tubering of the roots was controlled (1) by varying the moisture around the roots, (2) by varying the root temperature, and (3) by treating the leaves with growth regulators. When tubering was greatest, the total dry matter formed per unit area of leaf was also greatest. Benzyl adenine applied to the lamina increased the proportion of total dry matter in the tubers.

The results indicate that increasing tuber growth increases net assimilation rate, supporting the view that rate of photosynthesis depends on the capacity of sinks to accept photosynthate.

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5.6 THORNE, G. N. & (BLACKLOCK, J. C.) (1971) Effects of plant density and nitrogen fertiliser on growth and yield of short varieties of wheat derived from Norin 10. *Annals of Applied Biology* **68**, 93–111.

The short varieties of spring wheat, Lerma Rojo 64 (R) and Mexico 120 (M), derived from Norin 10, had similar yields of grain to the taller European variety, Kloka (K), when the nitrogen applied ranged from 50 to 200 kg/ha.

All varieties had their maximum yields of about 500 g/m² of grain, with 125 kg/ha of N. Yields of R and M were unaffected by change in plant population from 75 (M) or 105 (R) to 298 plants/m². There were 213 plants of K per m². When compared at similar plant populations, all varieties had a similar number of ears of similar weights. Ears of K had many small grains borne on many spikelets. Those of R had fewest spikelets and most grains per spikelet. With 213 plants/m² about 60% of shoots of K and 70% of those of R and M survived to produce ears.

The short variety of winter wheat Gaines (G), derived from Norin 10, had a similar yield of grain to the taller European variety Cappelle-Desprez (C), when nitrogen ranged from 75 to 300 kg/ha and there were 240 plants per m². The largest grain yields of both varieties, about 670 g/m², were obtained with 150 kg/ha of N. Increasing the plant population of G to 400 plants/m² decreased grain yield by 10%. G had more ears than C and the ears weighed less because the grains were smaller. The numbers of grains per ear were similar: ears of G had fewer spikelets than C, each bearing more grains. G always had more shoots than C and about 70% of the shoots produced by each variety survived to form ears.

The dry weight per m² of stem plus leaves of the short varieties was less than of the tall ones at flowering and at maturity. Hence harvest index (ratio of grain yield to total dry weight), and the proportion of total dry weight in the ears at flowering, were greater for the short than for the tall varieties.

Grain leaf ratio, the apparent efficiency of the leaf area present after flowering in producing grain, estimated as grain dry weight divided by leaf area duration after flowering, was greatest for M and least for K in the spring experiment. No similar difference occurred between the winter varieties. When leaf area of either spring or winter varieties was increased by nitrogen fertiliser or denser sowing, grain yield did not increase proportionately and so grain leaf ratio decreased.

5.7 WHEELER, A. W. (1971) Auxins and cytokinins exuded during formation of roots by detached primary leaves and stems of dwarf French bean (*Phaseolus vulgaris* L.). *Planta (Berlin)* **98**, 128–135.

Hypocotyls of detached stems standing in culture solution produced adventitious roots sooner than did petioles of detached primary leaves. An auxin, probably 3-indole acetic acid, appeared in the solutions before the hypocotyls or petioles produced roots. After attaining a maximum, the amounts of auxin in the solutions decreased as fewer roots were formed. Two cytokinins were found in the culture solutions; one had a similar R_f to zeatin, the other ran more slowly on chromatograms. Stems soon died unless their hypocotyls formed roots, but the primary leaves survived without roots forming provided a callus formed on the petiole. Hence adventitious roots, or callus tissues, may have produced cytokinins that replaced those produced by the original roots, found in sap exuded from the stem stumps, and were essential for survival of the stems and leaves.

5.8 WILLIAMS, E. D. (1971) Germination of seeds and emergence of seedlings of *Agropyron repens* (L.) Beauv. *Weed Research* **11**, 171–181.

Seeds of *Agropyron repens* (L.) Beauv, have little innate dormancy and germinate mainly during autumn, but germination may be delayed by cold, inadequate moisture or deep burial. Seedlings emerged from all viable seeds sown 5 cm deep but from only 4% of those 10 cm deep. Many seeds are viable when green and immature. At Rothamsted, spike emergence and flowering were earlier in 1970 than in 1968 and 1969 but more seeds became viable more rapidly in 1969. Higher temperatures in May and early June in 1970, and after flowering in 1969, probably account for most of these differences. Germination is facilitated by a diurnal alternation of temperature, but more old than young seeds can germinate at a constant temperature.

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5.9 WILLIAMS, E. D. (1971) Effects of light intensity, photoperiod and nitrogen on the growth of seedlings of *Agropyron repens* (L.) Beauv. and *Agrostis gigantea* Roth. *Weed Research* **11**, 159–170.

Seedlings of *Agropyron repens* (L.) Beauv. and *Agrostis gigantea* Roth. were grown in two light intensities with two photoperiods and with two amounts of nitrogen. On two occasions plants were also transferred between photoperiods.

The early growth of the seedlings was increased most by increasing the light intensity, but later nitrogen had the greatest effect. In short photoperiods, plants of both species were decumbent and had many more shoots than in long photoperiods. At the end of the experiment, plants of both species responded more to nitrogen in bright than in dim light and the dry weight of *Agropyron* was increased more than that of *Agrostis* by increased photoperiod and nitrogen.

Agropyron initiated rhizomes sooner than *Agrostis*; it had fewer rhizomes but they were longer and thicker and weighed more. Brighter light, longer photoperiod and nitrogen all increased rhizome weight. Photoperiod did this mainly by producing more rhizomes, light by increasing thickness or density, and nitrogen by both. The effects of photoperiod and nitrogen on the rhizome dry weight of *Agropyron*, but not of *Agrostis*, were additive.

Transferring plants from short to long photoperiods or from long to short, respectively increased or decreased total growth, but had an opposite effect on the rhizomes.

Biochemistry Department

BOOK

Leaf protein: *its agronomy*, *preparation*, *quality and use*. Ed. N. W. Pirie, International Biological Programme Handbook No. 20, Oxford: Blackwell, 192 pp. Contributions from Rothamsted are:

6.1 ARKCOLL, D. B. (1971) Agronomic aspects of leaf protein production in Great Britain, 9–18.

6.2 BYERS, M. (1971) The amino acid composition of some leaf protein preparations, 95–114.

6.3 PIRIE, N. W. (1971) A survey of other experiments on protein production, 29–43.

6.4 PIRIE, N. W. (1971) Equipment and methods for extracting and separating protein 53–62.

6.5 PIRIE, N. W. (1971) Drying, preservation, solvent extraction and separation into 'chloroplast' and 'cytoplasmic' fractions, 86–94.

6.6 PIRIE, N. W. (1971) The use of the by-products from leaf protein extraction, 135–137.

6.7 PIRIE, N. W. (1971) The presentation of leaf protein on the table, 155–163.

GENERAL PAPERS

6.8 HOLDEN, M. (1971) Hertfordshire fungus records. Agarics and Boleti 1951–1970. *Transactions of the Hertfordshire Natural History Society* **27**, 121–150.

6.9 PIRIE, N. W. (1971) Characteristics of living things. In: *International Encyclopedia of Food Nutrition* Ed. R. N. Fiennes, Oxford: Pergamon Press. **18**, 9–25.

6.10 PIRIE, N. W. (1971) Some obstacles to innovation. *Pugwash Newsletter* **9**, 16–22.

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6.11 PIRIE, N. W. (1971) Introduction to symposium: A discussion on optimal conditions for photosynthesis in a wholly artificial environment. *Proceedings of the Royal Society* (*B*) **179**, 173–175.

6.12 PIRIE, N. W. (1972) The biosphere without man. In symposium: *Ecology in theory and practice*. Institute of Contemporary Arts, A. P. Watt & Son.

6.13 PIRIE, N. W. (1972) Plants as sources of unconventional protein foods. In symposium: *The biological efficiency of protein production*. Reading: Cambridge University Press.

6.14 PIRIE, N. W. (1971) Comment on the 'green revolution'. *Proceedings of the 21st Pugwash Conference* (Sinaia, Rumania), 122–124.

6.15 PIRIE, N. W. (1972) The production of food proteins. In symposium: *Research and education in fundamental biology relevant to human welfare*. Seattle.

6.16 PIRIE, N. W. (1972) Academic aspects of applied research on food proteins. In symposium: *Research and education in developing countries*. Caracas, *Proceedings of 1st Pan-American Association of Biochemical Societies, R16*. Also in: *Proceedings of the 21st Pugwash Conference* (Sinaia, Rumania), 321–331.

6.17 PIRIE, N. W. (1972) The use of leaves as sources of food protein. Roopvati. (In the press.)

6.18 PIRIE, N. W. (1972) On recognising life. In: *Molecular evolution: Prebiological and biological*. Ed. D. L. Rohlfing, New York: Plenum Publishing Co.

RESEARCH PAPERS

6.19 ARKCOLL, D. B. & DAVYS, M. N. G. (1971) The production and use of leaf protein. *The Chemical Engineer* **251**, 261–264.

Growing plants specifically to produce leaf protein, and using machinery that extracts it efficiently, have given yields of 2000 kg/ha of good quality protein in a year. A 30 hp unit will extract up to 90% of the nitrogen from as much as two tons of crop in an hour.

The process is arousing increasing interest in the developing countries as a local method of alleviating protein malnutrition and it allows fodder to be used much more efficiently in countries such as the United Kingdom.

6.20 BAWDEN, F. C. & PIRIE, N. W. (1971) Factors affecting the infectivity of extracts from tobacco leaves infected with tobacco mosaic virus. *Proceedings of 1st Pan-American Association of Biochemical Societies*, R19.

In some circumstances, TMV : RNA, liberated from TMV by treatment with phenol in the presence of leaf pulp, becomes attached to the fibre, inactivated by small molecules in the extract, and hydrolysed by phenol-stable RNase.

6.21 HILL, J. M. (1972) The oxidation of Schiff bases of pyridoxamine with α-oxo acids by manganous ions and peroxidase. *Biochemical Journal*. (In the press.)

Mn^{2+} ions with pyruvate or another α-oxo acid catalyses the oxidative deamination of pyridoxamine to pyridoxal. The reaction starts after a lag period which is shortened by peroxidase but peroxidase does not affect the subsequent rate or the total amount of oxygen taken up.

6.22 JERVIS, L. (1972) Affinity chromatography of tobacco ribonuclease. *Biochemical Journal* **127**, 29P.

The preparation and use of three specific adsorbents based on guanosine 2′(3′) phosphate is described.

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Plant Pathology Department

General Papers

7.1 Bawden, F. C. (1971) Alfred Alexander Peter Kleczkowski, 1908–1970. *Biographical Memoirs of Fellows of The Royal Society* **17**, 430–440.

7.2 (Brunt, A. A.) & Kenten, R. H. (1971) Viruses infecting cocoa. *Review of Plant Pathology* **50**, 591–602.

7.3 Gregory, P. H. (1971) Airborne microbes: their significance and distribution. The Leeuwenhoek Lecture, 1970. *Proceedings of the Royal Society of London* (*B*) **177**, 469–483.

7.4 Gregory, P. H. (1971) The leaf as a spore trap. In: *Ecology of leaf surface micro-organisms*. Ed. T. F. Preece & C. H. Dickinson, London and New York: Academic Press, pp. 239–243.

7.5 Gregory, P. H. (1971) Black pod disease: the future. *Report 3rd International Cocoa Research Conference Accra, 1969*, pp. 365–369.

7.6 Hirst, J. M. (1969) Dissemination by wind; In: *Plant disease*, 3rd Ed. *McGraw-Hill Encyclopedia of Science and Technology*, pp. 365–366.

7.7 Hirst, J. M. & Stedman, O. J. (1971) Patterns of spore dispersal in crops. In: *Ecology of leaf surface micro-organisms*. Ed. T. F. Preece & C. H. Dickinson London and New York: Academic Press, pp. 229–237.

7.8 Kenten, R. H. & (Legg, J. T.) (1971) Varietal resistance of cocoa to swollen-shoot disease in West Africa. *F.A.O. Plant Protection Bulletin* **19**, 1–11.

7.9 Lapwood, D. H. & Hide, G. A. (1971) Potato diseases. In: *Diseases of crop plants*. Ed. J. H. Western, London: Macmillan, Chapter 7, pp. 89–122.

7.10 Salt, G. A. (1971) Conifer seedling pathology. *Report on Forest Research* (*London*) *1971*, pp. 131–132.

7.11 Waller, J. M. (1971) The spread of Coffee Rust. *SPAN* 14, Part 3, p. 142.

7.12 Watson, M. A. & Plumb, R. T. (1972) Aphid transmission of plant pathogenic virus. *Annual Review of Entomology* **17**, 425–452.

7.13 (Wellings, L. W) & Lapwood, D. H. (1971) Control of Common Scab by the use of irrigation. *N.A.A.S. Quarterly Review* No. 91, 128–137.

Research Papers

7.14 Bolton, J. & Slope, D. B. (1971) Effects of magnesium on cereals, potatoes and leys grown on the 'continuous cereals' site at Woburn. *Journal of Agricultural Science* (*Cambridge*) **77**, 253–259.

(For summary see No. 2.26.)

7.15 (Brunt, A. A.) & Kenten, R. H. (1972) Pepper veinal mottle virus—a new member of potato virus Y group from peppers (*Capsicum annuum* L. and *C. frutescens* L.) in Ghana. *Annals of Applied Biology* (1972). (In the press.)

Pepper veinal mottle virus (PVMV), a previously undescribed virus widespread in *Capsicum annum* and *C. frutescens* in the Eastern Region of Ghana, is transmitted in the non-

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persistent manner by aphids (*Myzus persicae* and *Aphia gossypii*), and by inoculation of sap to 11 of 15 Solanaceae and to five of 46 other species within three of 17 other families. The virus was propagated in *Nicotiana clevelandii* and *Petunia hybrida*, and assayed in *Chenopodium quinoa*, *C. amaranticolor* and *C. murale*. Sap from *Capsicum annum* was infective after dilution to 10^{-3} but not 10^{-4}, after 10 minutes at 55° but not 60°C, and after seven but not eight days at 25°C. Lyophilised sap from *P. hybrida* was infective after six years *in vacuo*.

Yields of 10–25 mg of virus per kg of leaf tissue were consistently obtained from *P. hybrida* or *N. clevelandii* by extracting systemically-infected leaves in 0·5*M* borate (pH 7·8) containing 0·2% mercapto-ethanol and chloroform, followed by repeated precipitation with 50 g polyethylene glycol (M.W. 6000) per litre, several cycles of differential centrifugation and centrifugation in sucrose density gradient columns.

Virus preparations had ultra-violet absorption spectra typical of a nucleoprotein containing *c.* 6% nucleic acid (A 260/280 = 1·25; A 260/246 = 1·27) and contained numerous unaggregated and unbroken filamentous particles *c.* 770 × 12 nm which sedimented as a single component with a sedimentation coefficient (S°_{20w},) of 155 *S*. PVMV contained RNA (G = 24%, A = 23%, C = 27%, U = 26%), and a single protein species with a molecular weight of 32 000–33 000 daltons. PVMV was not serologically related to potato virus Y (three strains), bean yellow mosaic, tobacco severe etch, turnip mosaic virus (three strains), henbane mosaic and eight other morphologically similar viruses, and seems to be a distinct member of the potato virus Y group.

The cryptogram of PVMV is R/(1) : *(6) : E/E : S/Ap.

7.16 COCKBAIN, A. J. (1971) Epidemiology and control of weevil-transmitted viruses in field beans. *Proceedings of the 6th British Insecticide and Fungicide Conference (1971)* **1**, 302–306.

Broad bean stain virus and Echtes Ackerbohnemosaik-Virus sometimes cause indistinguishable mottle and masaic leaf symptoms in field beans. Combined incidence of the two viruses ranged from 2 to 92% in nine crops of field beans examined in 1970 and 1971. Early infection of field beans by either virus can decrease yield by *c.* 70%. Both viruses are transmitted through seed and by adult weevils of the genera *Apion* and *Sitona*. Of treatments tested, aldicarb applied to the soil at drilling time controlled adult weevils best and checked spread of both viruses; gamma BHC applied to the foliage was much less effective.

7.17 CORBETT, D. C. M. & HIDE, G. A. (1971) Interactions between *Heterodera rostochiensis* Woll. and *Verticillium dahliae* Kleb. on potatoes and the effect of CCC on both. *Annals of Applied Biology* **68**, 71–80.

(For summary see No. 8.7.)

7.18 CORBETT, D. C. M. & HIDE, G. A. (1971) Chemical control of *Verticillium dahliae* and *Heterodera rostochiensis* on potatoes. *Proceedings of the 6th British Insecticide and Fungicide Conference (1971)* **1**, 258–262.

7.19 EBBELS, D. L. (1971) Effects of soil fumigation on soil nitrogen and on disease incidence in winter wheat. *Annals of Applied Biology* **67**, 235–243.

Winter wheat was grown in soil fumigated with 'D–D', 85% dazomet dust or formalin, and top-dressed with 0 or 125 kg nitrogen/ha. Six weeks after fumigation, there was much more ammonium nitrogen in fumigated than in unfumigated soil. Nitrate was also more after fumigation with dazomet, but less after 'D–D' and formalin. After five months, only 'D–D' plots had less nitrate and more total mineral nitrogen than unfumigated plots.

Take-all (*Ophiobolus graminis*) was less prevalent in the first crop after dazomet or formalin, but was more prevalent in the second crop than after other treatments. Eyespot (*Cercosporella herpotrichoides*) was decreased only by formalin and only in the first crop after applying it. Fumigation has little effect on the incidence of other diseases recorded or on grain yield, except that yields were light on 'D–D' plots in the first crop after fumigation, when ears were severely deformed.

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7.20 GOVIER, D. A. & WOODS, R. D. (1971) Changes induced by magnesium ions in the morphology of some plant viruses with filamentous particles. *Journal of General Virology* **13**, 127–132.

Particles of henbane mosaic virus in extracted plant sap were usually straight and 900 nm long but occasionally flexuous and 800 nm long. The length and flexuousness of the particles depended on the composition of the extracting medium. When exposed to magnesium ions (0·05*M*), the particles were long and straight but when exposed to 0·05*M*-EDTA they were shorter and flexuous. Similar morphological differences were found when pepper veinal mottle virus or bean yellow mosaic virus was extracted in the two solutions. With pepper veinal mottle virus, each form of particle could be converted to the other by changing the medium.

7.21 KASSANIS, B. & BASTOW, C. (1971) *In vivo* phenotypic mixing between two strains of tobacco mosaic virus. *Journal of General Virology* **10**, 95–98.

PM_2, a mutant of tobacco mosaic virus, has a defective protein and exists in the plant as free RNA. When inoculated together with the cowpea strain of tobacco mosaic virus, under conditions when both can multiply, the RNA of PM_2 can become coated with the protein of cowpea mosaic virus and thus becomes stable.

7.22 KASSANIS, B. & BASTOW, C. (1971) The relative concentration of infective intact virus and RNA of four strains of tobacco mosaic virus as influenced by temperature. *Journal of General Virology* **11**, 157–170.

The multiplication of four strains of tobacco mosaic virus was compared at temperatures of 20° to 25°C and at 35°C by estimating the concentration of total infective virus RNA, intact virus, virus antigen and insoluble virus protein in plants at different times after inoculation. The four strains were: the type strain, nitrous acid mutants PM2 and Ni118, and the 'thermophilic' strain TC. The concentration of total infective RNA of all four strains reached it maximum concentration about a week after inoculation and was about ten times greater at 20° than at 35°C, but the infectivity of intact virus and the virus antigen titre varied with the strain. The intact virus and virus antigen concentrations of the type strain were decreased similarly to the RNA concentration when the temperature was raised. Ni118 produced very little infective intact virus at 35° but as much at 20°C as the type strain, although the particles were less well formed. Intact virus of PM2 was not found at any temperature so the virus protein seems non-functional. The strain TC produced about as much infective intact virus at 35°C as the type strain but much less virus at 20°C than at 35°C.

Virus multiplication of the four strains was affected by increased temperature in two ways: (1) the replication of the RNA of all strains was inhibited; (2) the RNA of those strains with defective protein was degraded. Degradation was most obvious with PM2, the infectivity of which, after a maximum was reached, declined increasingly fast with increasing temperature. Free RNA of Ni118 accumulated at 35°C because the protein became insoluble but, in contrast to PM2, some complete virus was produced. There was no free RNA in plants infected with type strain. The apparently greater infectivity of TC at 35°C than at 20°C resulted from the fact that its RNA is badly coated at 20°C, forming unstable particles. The concentrations of total infective RNA of type strain and TC at 35°C did not differ.

When infected plants were transferred from 35° to 20°C, the infectivity of intact virus increased with the type strain and still more with Ni118.

7.23 KASSANIS, B. & BASTOW, C. (1971) Phenotypic mixing between strains of tobacco mosaic virus. *Journal of General Virology* **11**, 171–176.

Strain Ni118 of tobacco mosaic virus in tobacco plants kept at 35°C exists mainly as free virus RNA and insoluble virus protein but also forms a few intact virus particles. Buffer extracts of infected leaves have, therefore, very little infectivity. Similar extracts from plants inoculated with a mixture of Ni118 and the type strain tested on plants in which only Ni118 gives symptoms are very much more infective (40 to 500 times). The increase in the Ni118 infectivity of leaf extracts is even greater when the leaves are infected with the Nigerian cowpea virus instead of the type strain. The cowpea virus is a strain of tobacco mosaic virus only slightly serologically

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related to Ni118. Neutralisation of infectivity tests, using homologous and heterologous antisera, showed that the increased infectivity of Ni118 in dual infections is caused by the nucleic acid of Ni118 being incorporated in protein of Nigerian cowpea virus.

7.24 KASSANIS, B. & GOVIER, D. A. (1971) New evidence on the mechanism of aphid transmission of Potato C and Potato Aucuba Mosaic Viruses. *Journal of General Virology* **10**, 99–101.

7.25 KASSANIS, B. & GOVIER, D. A. (1971) The role of the helper virus in aphid transmission of Potato Aucuba Mosaic Virus and Potato Virus C. *Journal of General Virology* **13**, 221–228.

Potato aucuba mosaic virus and potato virus C were transmitted by the aphid *Myzus persicae*, not only from plants also infected with a helper virus, but also from plants infected with them alone, provided the aphids fed first on plants infected with the helper virus. Several different viruses acted as helpers but all are in the potato virus Y group. Helper viruses differed in the efficiency with which they aided potato aucuba mosaic virus and potato virus C, and some potato aucuba mosaic virus isolates were transmitted more frequently than others. With potato virus Y as helper, up to 30% of the aphids transmitted potato aucuba mosaic virus. Aphids were usually fed for brief periods on plants infected with the helper virus but aphids fed for two days also transmitted potato aucuba mosaic virus readily. Starving the aphids for one to two hours between their acquisition feeds on plants infected with helper and aided virus decreased but did not eliminate transmission.

The helper virus need not be infective; potato aucuba mosaic virus and potato virus C were transmitted as frequently when transmission of the helper virus was prevented by exposing the source leaf to UV radiation as when it was not. Virus was not transmitted by aphids fed through artificial membranes on extracts of leaves infected with potato virus Y, potato aucuba mosaic virus or a mixture of the two. However, potato aucuba mosaic virus was transmitted from extracts by aphids fed through membranes when the aphids had previously fed on a leaf infected with potato virus Y. Similarly, potato virus Y was transmitted from leaf extracts by aphids fed through membranes when the aphids had previously fed on a potato virus Y-infected leaf that had been irradiated with UV to prevent transmission of potato virus Y from this source.

Possible mechanisms for the transmission of the helper and aided viruses are discussed.

7.26 KASSANIS, B. & MILNE, R. G. (1971) An unusual inclusion in plants infected with a Tobacco Mosaic Virus mutant. *Journal of General Virology* **11**, 193–195.

7.27 KENTEN, R. H. & (LEGG, J. T.) (1971) Serological relationships of some viruses from cocoa (*Theobroma cacao* L.) in Ghana. *Annals of Applied Biology* **67**, 195–200.

Strains A and Anibil of cocoa swollen-shoot virus are serologically closely related. They are more distantly related to strain M and cocoa mottle-leaf virus (Kpeve isolate), which are distantly related to one another. Strains A and Anibil protected against one another in cocoa seedlings, but no protection was found with any other combination between these four virus isolates. All mealybug-transmitted cocoa viruses in West Africa are probably best considered as strains of cocoa swollen-shoot virus.

7.28 LACEY, J. (1971) *Thermoactinomyces sacchari* sp. nov., a thermophilic actinomycete causing bagassosis. *Journal of General Microbiology* **66**, 327–338.

A new species of thermophilic monosporic actinomycete, isolated from mouldy sugar cane bagasse, is described as *Thermoactinomyces sacchari* sp. nov. It is distinguished from *T. vulgaris* Tsiklinsky by short tufted aerial mycelia that rapidly autolyse and are not always seen, by bearing spores on short sporophores, by its appearance on different culture media and by serological differences. Both species have heat-resistant spores containing dipicolinic acid and with the structure of bacterial endospores. A sufferer from bagassosis who inhaled extracts of *T. sacchari* developed symptoms characteristic of the disease.

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7.29 LACEY, J. (1971) The microbiology of moist barley storage in unsealed silos. *Annals of Applied Biology* **69**, 187–212.

The microflora of moist barley grain and whole-crop barley silage stored in top-unloading, unsealed concrete-staved silos on six farms in England depended on the initial water content of the grain (23–58%), method of covering the grain, and the rate at which it was unloaded. Fungi and actinomycetes were fewest when the initial water content exceeded 30%, and the grain was covered first with a layer of wilted grass, and then a plastic sheet. During unloading, the uppermost layer of grain remained in good condition provided 7·5 cm was removed daily.

With an inefficient top-seal, the top grain heated and became mouldy, as it also did when unloading was slow. As the rate of unloading slowed, heating increased, and a characteristic succession of fungi and actinomycetes developed. With unloading at 7·5 cm/day or more, only yeasts, chiefly *Endomycopsis chodatii* Wickerham and *Hansenula anomala* (Hansen) H. & P. Sydow, were abundant but at slightly slower rates of unloading *Penicillium* sp. also became common. Both these groups became less common as unloading was slowed further and were replaced, first by *Absidia* spp. and *Mucor pusillus* Lindt, then *Aspergillus fumigatus* Fres., *Humicola lanuginosa* (Griffon & Maublanc) Bunce, *Micropolyspora faeni* Cross, Maciver and Lacey, and *Thermoactinomyces vulgaris* Tsiklinsky as the heating increased. The number of spores (including bacterial cells) that could be removed from samples by blowing air ranged from 0·4–428 $\times$ 10^6/g dry weight of grain. Whole-crop barley silage contained 2·9–132 $\times$ 10^6 spores/g dry weight. Similar species were isolated from whole crop silage as from grain. Little moulding occurred deeper than 30 cm below surface of the grain.

Concentrations of airborne spores were estimated periodically during two seasons. There were always more airborne spores than is usual in outdoor air. Without disturbance the silos contained 10^6–10^7 spores/m^3 air, but when mouldy grain was unloaded concentrations increased to a maximum of 2860 $\times$ 10^6/m^3 air, more than half of these were bacteria and actinomycetes, and a quarter, *Aspergillus flavus* Link. Potentially pathogenic fungi and actinomycetes were frequent, particularly when they also occurred in the grain or capping materials after sponteneous heating. Some probably survived in dust deposits and were resuspended during unloading. Airborne spores were frequent around the silos when grain was being unloaded and rolled. Workers should wear efficient dust respirators at these times and while inside silos.

7.30 LACEY, J. (1972) The microbiology of grain stored underground in Iron Age-type pits. *Journal of Stored Products Research*. (In the press.)

Barley grain was stored underground in Iron Age-type pits in Wiltshire in two seasons. The grain stored well during the first season after harvesting with 14 to 21% water content. Moulding was slight, except near the outside of the grain mass, and *Penicillium cyclopium* predominated. Grain with 26% water content was stored in the second season. This, combined with wetter weather, resulted in spontaneous heating and the growth of thermophilic and thermotolerant fungi and actinomycetes.

7.31 LACEY, J. & VINCE, D. A. (1972) Endospore formation and germination in a new *Thermoactinomyces* species. In: *Spore research—1971*. Ed. A. N. Barker, G. W. Gould and J. Wolf. London: Academic Press, pp. 181–188.

Endospores of *Thermoactinomyces sacchari* develop and germinate by stages similar to those described for endospores of *Bacillus* species and *Thermoactinomyces vulgaris*. A forespore, surrounded by a double membrane, was developed in cells of the septate mycelium. Cells containing forespores grew short sporophores with the forespore terminal. A cortex formed between the two membranes, and a multi-layered inner and ridged outer spore coat formed around the outer membrane. The mature spore was surrounded by a membrane that may have been an exosporium or the remains of the sporangium. During germination, the cortex disappeared and the spore doubled in size, fragmenting the spore coats, before a germ tube was formed.

7.32 LAPWOOD, D. H. (1971) Observations on blight (*Phytophthora infestans*) and resistant potatoes at Toluca, Mexico. *Annals of Applied Biology* **68**, 41–53.

A late blight epidemic studied at Toluca, Mexico, in 1962 may have started from stems infected at soil level by soil-borne *Phytophthora infestans*. Its severity was demonstrated by the large

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differences in the rate foliage was destroyed and in yield of tubers between fungicide-sprayed and unsprayed susceptible and resistant cultivars. The foliage resistances of some Mexican and European cultivars were compared using conventional blight keys and recording the destruction of marked leaves. Cultivars reacted in four ways: (1) Up-to-Date and Alpha leaves were infected and killed soon after plants emerged; (2) Bertita, Conchita and Florita abscissed many infected lower-canopy leaves, and many infections on upper leaves aborted; (3) Elenita leaves had a few lesions in which the fungus grew slowly but remained alive; (4) Greta showed no infection until the potato plants met between rows but then infections developed rapidly and the foliage soon died. Mexican cultivars, except for Elenita, had few blighted tubers; susceptible European cultivars were killed before many tubers formed.

Most spores were released during the morning, as in Europe, and leaf infection seemed associated with days with rain when much of the night remained humid. Cool nights lengthened incubation and generation times.

7.33 LAPWOOD, D. H., (WELLINGS, L. W. & HAWKINS, J. H.) (1971) Irrigation as a practical means to control potato common scab (*Streptomyces scabies*). *Plant Pathology* **20**, 157–163.

Irrigation in 1970 at Gleadthorpe E. H. F. increased potato yields and, when given from the time of tuber initiation, controlled common scab on the susceptible cultivars King Edward, Majestic and Record. Pentland Crown had little scab with or without irrigation. It was the driest May and June since 1934 and there was already a soil moisture deficit (SMD) of 1·8 in. (46 mm) at tuber initiation by King Edward and when water was first given. Subsequently irrigation at 0·6 in. (15 mm) or 0·8 in. (20 mm) SMD was more effective than 1·5 in. (38 mm) or 2·25 in. (57 mm) SMD in controlling scab, and more effective at 0·6 in. SMD when maintained for four weeks than for two weeks.

Irrigation at 0·6 in. SMD for four weeks increased the weight of premium (Table Grade) potatoes by respectively, 16, 12, 13, and 12 tons/acre (40, 30, 32·5 and 30 t/ha) for King Edward, Majestic, Record and Pentland Crown.

Tubers developed slowly in unirrigated plots both in volume and in the rate that eyes separated. King Edward produced more tubers per plant than Majestic; irrigation did not increase tuber numbers.

7.34 (LEGG, J. T.) & KENTEN, R. H. (1971) Field experiments on the resistance of cocoa to cocoa swollen-shoot virus. *Annals of Applied Biology* **67**, 369–375.

Progenies from crosses between different Upper Amazon cocoa types and between Upper Amazon and Amelonado were compared for their field resistance to infection with cocoa swollen-shoot virus (CSSV) virulent strain A. Among the intra-Amazon progenies, those from crosses of Scavina, Iquitos and Nanay groups showed most resistance. Progenies from crosses within these groups may be resistant enough to be of immediate practical value in decreasing losses in areas where CSSV is widespread. Some Nanay progenies were more resistant than others and this provides scope for improvement by breeding. Progeny of crosses between Upper Amazon and Amelonado parents were less resistant than those from intra-Amazon crosses.

7.35 PLUMB, R. T. (1971) European wheat striate mosaic disease in 1970. *Plant Pathology* **20**, 120–122.

European wheat striate mosaic was more prevalent in English winter wheat crops in 1970 than in any previous year and in one crop yield loss was probably 10%.

At Rothamsted, infected plans were first found at the beginning of May and symptoms appeared in others until the middle of June. Most infections probably occurred before spring cereals emerged but a few plants became infected in spring-sown crops. Most infected plants produced no grain. The mild autumn of 1969 and a previous crop of spring wheat may partly explain its unusual prevalence at Rothamsted.

7.36 PLUMB, R. T. (1971) The control of insect-transmitted viruses of cereals. *Proceedings of the 6th British Insecticide and Fungicide Conference 1971* **1**, 307–313.

Barley yellow dwarf virus is the most widespread and damaging of insect-transmitted viruses of cereal crops in Britain but the losses it causes differ greatly in different parts of the country

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and from year to year. Isolates of the virus differ in virulence and not all are transmitted equally well by the several species of aphid vector. Crops in south and south-western counties are worst affected because the mild winters enable vectors to overwinter on hosts of the virus infected with virulent isolates.

Field studies of the occurrence of infective aphids in eastern counties have helped to show when insecticides should be applied, but the virus spread too little in the experiments for spraying to have large effects on yield. It is hoped that virus incidence can eventually be predicted from knowledge of overwintering vectors and when and how many carry virus into the crops.

7.37 PLUMB, R. T. & VINCE, D. A. (1971) Fixation and electron microscopy of the Rothamsted culture of henbane mosaic virus. *Journal of General Virology* **13**, 357–359.

7.38 SALT, G. A. & HORNBY, D. (1971) Root rot and wilt of field beans (*Vicia faba*). *Proceedings of the 6th British Insecticide and Fungicide Conference 1971* **1**, 251–257.

Wilted field beans with blackened tap roots and few functional laterals are common and were widespread in 1970 when many crops were stunted, yellow and yielded very little. Possible causes include the pea and bean weevil, *Sitona lineatus*, which damages leaves and roots and transmits viruses; the stem eelworm, *Ditylenchus dipsaci*; the fungi *Fusarium oxysporum*, *F. avenaceum*, *Rhizoctonia solani*, *Pythium* spp. and *Phytophthora megasperma*. In field experiments, aldicarb, which is insecticidal and nematicidal, and the fungicide, 'Dexon', both strikingly decreased wilt symptoms and increased growth and yield; benomyl had less effect, formalin and BHC least of all. Only *P. megasperma* caused root rot and wilt of plants inoculated in pots, but was not found regularly in rotted roots from the field.

7.39 TRUDGILL, D. L. & CARPENTER, J. M. (1971) Disk electrophoresis of proteins of *Heterodera* species and pathotypes of *Heterodera rostochiensis*. *Annals of Applied Biology* **69**, 35–41.

(For summary see No. 8.18.)

7.40 TURNER, R. H. (1971) Electron microscopy of cells infected with narcissus mosaic virus. *Journal of General Virology* **13**, 177–179.

Nematology Department

GENERAL PAPERS

8.1 CORBETT, D. C. M. & HIDE, G. A. (1971) Chemical control of *Verticillium dahliae* and *Heterodera rostochiensis* on potatoes. *Proceedings of the 6th British Insecticide and Fungicide Conference (1971)* **1**, 258–262.

8.2 WHITEHEAD, A. G. (1972) Nematicides for field crops. *Proceedings of the 6th British Insecticide and Fungicide Conference (1971)* **3**, 662–672.

8.3 YEATES, G. W. (1971) Plant and soil nematodes of Wicken Fen. *Nature in Cambridgeshire* **14**, 23–25.

RESEARCH PAPERS

8.4 (ANDERSON, R. V.) & HOOPER, D. J. (1971) A neotype for *Eucephalobus striatus* (Bastian, 1865) Thorne, 1937 (Nematoda) and redescription of the species from topotypes and their progeny. *Canadian Journal of Zoology* **49**, 451–459.

The dimensions and morphology of the progeny of five females of *Eucephalobus striatus* cultures on agar ranged more widely than in previous descriptions. Specimens from agar were usually longer and wider than specimens from soil and differ in some other respects. First-generation larvae developed slowly on agar, requiring at least a month to become adult. Adult females from agar rarely reproduced, and their gonads differed from those of impregnated, fecund specimens

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from soil. Some features of the lips and the variability of tails of the females showed the close similarities to *Cephalobus persegnis* Bastian, 1865. Length and shape of the postuterine sac, length of the gubernaculum compared with spicule length, and the position where the incisures ended on the female tail, were the most reliable characters for species identification but of doubtful generic value.

8.5 BROWN, G., CALLOW, R. K., GREEN, C. D., JONES, F. G. W., RAYNER, J. H., SHEPHERD, A. M. & WILLIAMS, T. D. (1971) The structure, composition and origin of the sub-crystalline layer in some species of the genus *Heterodera*. *Nematologica* **17**, 591–599.

The sub-crystalline layer from lemon-shaped females of *Heterodera* spp. was examined by the scanning electron microscope, X-ray diffraction, X-ray fluorescence spectrometry and mass spectrometry. The inner zone of the layer in *H. mani*, consisted almost entirely of n-tetracosanoic acid, and the outer, thicker, zone of a mixture of the acid and its calcium salt. In addition to this acid, in the layer *H. avenae* had up to 25% hexacosanoic acid and in *H. trifolii* three additional aliphatic acids, do-, tetra-, and hexa-cosanoic.

The outer layer fractures into pyramidal blocks presenting an irregular polygonal appearance. The fatty acid seems to be produced by an unidentified fungus that metabolises products excreted by the nematode. The layer of acid and its calcium salt may act as a barrier to potential pathogens and predators. The relationship between the nematode and fungus seems to be symbiotic.

8.6 CORBETT, D. C. M. (1972) The effect of *Pratylenchus fallax* Seinhorst on wheat, barley and sugar beet roots. *Nematologica* **18**. (In the press.)

Pratylenchus fallax penetrated root tips, the region of root hair development and the junction of main and lateral roots of wheat, barley and sugar beet. In microbiologically sterile cultures, roots of sugar beet rapidly became necrotic: barley and wheat roots were damaged less and more slowly. Transverse sections of wheat roots showed that cells were severely damaged and collapsed before symptoms showed externally. The endodermis became thickened and discoloured in response to heavy attack. *P. fallax* reproduced better on roots of wheat and barley than on those of sugar beet.

8.7 CORBETT, D. C. M. & HIDE, G. A. (1971) Interactions between *Heterodera rostochiensis* Woll. and *Verticillium dahliae* Kleb. on potatoes and the effect of CCC on both. *Annals of Applied Biology* **68**, 71–80.

H. rostochiensis (British pathotype A) increased the severity of the disease caused by *Verticillium dahliae* in potato plants grown in pots when there were more than 10 eggs/g of soil and both pathogens parasitised the root system together. The growth-suppressing chemical chlormequat chloride (CCC) severely stunted plants, prevented wilt and decreased the reproduction of *H. rostochiensis*.

8.8 EVANS, K. & TRUDGILL, D. L. (1971) Effects of amino acids on the reproduction of *Heterodera rostochiensis*. *Nematologica* **17**, 495–500.

Of several racemic mixtures of amino acids tested, the most toxic to *H. rostochiensis* and the least toxic to potato plants was DL-methionine. The D- and L- forms were equally toxic to the nematodes which became less sensitive as they aged. Methionine did not act directly by contact with the nematode but only when taken up by the host plant: it was presumably ingested in sap extracted from giant cells. Although methionine affected populations of *H. rostochiensis* in field plots, even large amounts failed to control the pest.

8.9 FRANKLIN, M. T., CLARK, S. A. & COURSE, J. A. (1971) Population changes and development of *Meloidogyne naasi* in the field. *Nematologica* **17**, 575–590.

To estimate the number of larvae and eggs of *M. naasi* larvae in soil, samples were incubated, with or without previous chilling, to cause unhatched larvae to hatch so that they could be extracted with the free larvae. A week at 20°C, after a week at 0°, gave the most larvae from samples taken in autumn. Many fewer larvae were extracted from samples after storing at 30° than at

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15°, 20° or 25°C. In the field larvae were most abundant in early May and, in the presence of a host crop, populations then rapidly decreased to be followed by a slow increase from August to a small peak in October. Without a good host, populations remained large through June and July, then decreased gradually. Incubation always increased the number of larvae, but especially during April and during October after growing a host crop. The larvae developed in barley and ryegrass much as described for other species of *Meloidogyne*: a long period of feeding by the second stage larvae was followed by a short moult without feeding and then a period of resumed feeding and rapid growth by the adult female. In the field, the time between the larvae entering roots and becoming adult depended on soil temperature; the shortest time was in June and July, but the number of day-degrees above an assumed minimum of 12°C was similar through the year.

8.10 GOWEN, S. R. (1971) *Tylenchus emarginatus* and *Tylenchorhynchus dubius* associated with Sitka spruce (*Picea sitchensis*) seedlings. *Plant Pathology* **20**, 69–72.

Sitka spruce growing in tubes was a good host for *Tylenchus emarginatus* and *Tylenchorhynchus dubius*, which stunted the growth of roots. Both species were more abundant at Woburn, Bedfordshire, where Sitka spruce has been grown repeatedly than in nearby land under other crops. In 1968 nematodes were more numerous in plots with nitrogen fertiliser than in those without, but in 1969 were fewer, possibly because populations remaining from 1968 were too great for the seedlings to support or because rainfall was much less.

8.11 GREEN, C. D. (1971) The morphology of the terminal area of the round-cyst nematodes, *Heterodera rostochiensis* and allied species. *Nematologica* **17**, 34–46.

Between the vulva and the tail of round-cyst nematodes, *Heterodera* s.g. *Globodera*, is an area of transversely ridged cuticle containing the anus. Differences in the size of this area divide the group into two and differences in the number of ridges and the type of branching subdivide each group further. The vulva is a shallow pit the walls of which carry two crescentic papillated areas. Their size and the form of the papillae and the differences in the terminal area, can be used to distinguish species and pathotypes. The morphological differences between *H. rostochiensis* pathotypes A, B and E (British notation) are as great as those between described species. The group has probably diversified because populations are isolated and inbred.

8.12 HOOPER, D. J. (1971) Stem eelworm (*Ditylenchus dipsaci*), a seed and soil-borne pathogen of field beans (*Vicia faba*). *Plant Pathology* **20**, 25–27.

Both the 'oat race' and 'giant race' of *Ditylenchus dipsaci* (Kühn) Filipjev infest field beans (*Vicia faba* L.) in Great Britain and the infested seed sometimes produced is an important means of spreading them. The large soil populations, especially of the 'oat race', produced in beans from infested seed may damage following crops of beans, peas, sugar beet or, especially, susceptible oats. Bean seed for sowing should be saved only from uninfested fields, and only oat varieties that resist *D. dipsaci* should be grown in crop rotations that include beans.

8.13 HOOPER, D. J. & DONCASTER, C. C. (1972) Stem and inflorescence galls on yarrow (*Achillea millefolium* L.) caused by the nematode, *Anguina millefolii* (Löw, 1874) Filipjev, 1936. *Plant Pathology* **21**, 46.

The first report of stem and leaf galls caused by *Anguina millefolii* on influorescence of yarrow.

8.14 HOOPER, D. J. & (MYERS, R. F.) (1971) *Aphelenchoides rutgersi* n. sp. (Nematoda : Aphelenchoidea), description and morphometrics, with observations on *A. dactylocercus* Hooper, 1958 and *A. cibolensis* Riffle, 1970. *Nematologica* **17**, 295–302.

The *Aphelenchoides* sp. long studied at Rutgers University, U.S.A., and formerly thought to be *A. sacchari* or *A. dactylocercus* is described as *Aphelenchoides rutgersi* n. sp. Some variants resemble *A. cibolensis*, the male of which is also described. The body length, gonad length and tail shape of females, the progeny of single females cultured on *Pyrenochaeta terrestris* or *Botrytis cinerea*, vary greatly according to type of culture. Small but consistent differences distinguish *A. rutgersi* from the above species. The female has three lateral incisures, a short

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post-vulval sac about one and a half vulval body-widths long and a conoid tail about three anal body-widths long. The shape of the tail terminus is variable but usually has a short ventral mucro. The stylet is 10 μm long. Males are very rare.

8.15 SHEPHERD, A. M., CLARK, S. A. & DART, P. J. (1972) Cuticle structure in the genus *Heterodera*. *Nematologica* **18**, 1–17.

The cuticle of *H. rostochiensis* males and of the females of 14 species or pathotypes of *Heterodera* was examined with light and electron microscopes. The layers of the male cuticle resemble those of the second-stage larva and other vermiform Tylenchida so far described. The cuticle of females differs from this basic pattern in ways that fit their swollen form and sedentary habits, and their ultimate function as a protective cyst enclosing the quiescent eggs. The outer and inner layers, A and B, of males and larvae are supplemented by a third, fibrous layer, C, in lemon-shaped and round-cyst nematodes and by a fourth layer, D, in round-cyst nematodes only. The fibres in D are arranged helicoidally as in the chitin of insect endocuticle. The B layer of larvae and males is crystalloid, with disjunctions in the regular pattern at every half-annule. The periodicity of the pattern is 18–22 nm, as in one of the forms of collagen. The B layer ruptures as the females swell and ultimately occurs as separate islands at the junction of the A and C layers.

The differences in structure between the species with lemon-shaped and round cysts supports placing the round-cyst species (excluding *H. punctata*) into the separate genus *Globodera*, already suggested by Skarbilovich as a sub-genus.

8.16 STONE, A. R. (1971) Effect of processing on measurements of *Heterodera rostochiensis* larvae. *Nematologica* **17**, 167–171.

Some commonly used methods of processing larvae of *Heterodera rostochiensis* for microscopical examination cause changes in body and stylet size, greater than the difference between pathotypes. Heat and cold formalin, which caused least change, are suggested as the standard methods of killing and fixing larvae to be measured.

8.17 STONE, A. R. & GREEN, C. D. (1971) A simple method of preparing nematodes for scanning electron microscopy. *Nematologica* **17**, 490–491.

Preparing nematodes for scanning electron microscopy usually involves removing liquid under vacuum, which causes much distortion. There is little distortion when water is slowly replaced with acetone, which is then evaporated away before the specimens are coated with gold. Useful results at up to 25 000 × magnification have been obtained with *Heterodera* larvae and males.

8.18 TRUDGILL, D. L. & CARPENTER, J. M. (1971) Disk electrophoresis of proteins of *Heterodera* species and pathotypes of *Heterodera rostochiensis*. *Annals of Applied Biology* **69**, 35–41.

The proteins extracted by aqueous buffer from the females of six *Heterodera* spp. were separated into bands by polyacrylamide gel electrophoresis and the patterns compared. *Heterodera schachtii* and *H. trifolii*, with lemon-shaped cysts, had a similar pattern of bands, differing greatly from that of the round-cyst nematodes *H. virginiae* and *H. rostochiensis*. Ten British pathotype A populations of *H. rostochiensis* had similar patterns, distinguishable from those of 12 British pathotype E populations by lacking two bands and by the presence of another rare in pathotype E. Bands from pathotype B populations were indistinguishable from those of pathotype E. No consistent difference was detected between populations of the same pathotype. These results support the suggestion that *H. rostochiensis* comprises two species.

8.19 TRUDGILL, D. L. & PARROTT, D. M. (1972) Disc electrophoresis and larval dimensions of British, Dutch and other populations of *Heterodera rostochiensis* Woll., as evidence of the existence of two species, each with pathotypes. *Nematologica* **18**, 141–148.

Larval measurements, female colour and the results of electrophoresis in polyacrylamide gel indicate that *H. rostochiensis* should be split into two species. Each of these species contains

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pathotypes, so a modified scheme of pathotype nomenclature is suggested. Dutch and British pathotypes A are probably identical, and the Dutch pathotype D is the same as the British E. Populations such as the Dutch pathotypes B and C, and a population from Bolivia, which all have pathotype A characteristics but can reproduce on ex *andigena* hybrids, have not so far been found in Great Britain.

8.20 WEBB, R. M. (1971) Extraction of nematodes from sterile culture. *Nematologica* **17**, 173–174.

Apparatus is described for extracting small vermiform nematodes bacteriologically sterile from infested aseptic plant tissues.

Insecticides and Fungicides Department

GENERAL PAPERS

9.1 ELLIOTT, M. (1970) The relationship between the structure and the activity of pyrethroids. *Bulletin of the World Health Organisation* **44**, 315–324.

9.2 (HOCKING, K. S.) & POTTER, C. (1972) Problems on the use of insecticides in the tropics. *Proceedings of the 6th British Insecticide and Fungicide Conference* **3.** (In the press.)

9.3 LORD, K. A., JEFFS, K. A. & (TUPPEN, R. J.) (1971) Limitations of seed-treatments for pest control. *Proceedings of the 6th British Insecticide and Fungicide Conference* **1**, 9–14.

9.4 POTTER, C. (1972) Radioisotopes to estimate the dispersal of insecticides in the environment and irradiation techniques for the study of insect populations. In: *International Symposium on the Use of Isotopes and Radiation in Agriculture and Animal Husbandry Research 29 November–2 December 1971.* Nuclear Research Laboratory, Indian Agricultural Research Institute, New Delhi. (In the press.)

9.5 STEVENSON, J. H. (1971) Bee poisoning in 1970. *Bee World* **52**, 75–76.

RESEARCH PAPERS

9.6 (AKHTAR, M., BAIG, M. M. H.) & LORD, K. A. (1970) An assay of 'Sevin' formulations using micro steam distillation and its application to study of insecticide distribution in granules. *Pakistan Journal of Scientific and Industrial Research* **13**, 452–456.

Assay of carbaryl ('Sevin') by alkaline hydrolysis followed by distillation and titration of the methylamine formed was adapted for rapidly assaying many samples by using a micro kjeldahl type distillation.

Fine dust amounting to about 2% of a 'Sevin' granule was shown to contain three times the average concentration of the formulation, sufficient to cause sampling and analytical problems.

9.7 (BARLOW, F.), ELLIOTT, M., FARNHAM, A. W., (HADAWAY, A. B.), JANES, N. F., NEEDHAM, P. H. & (WICKHAM, J. C.) (1971) Insecticidal activity of the pyrethrins and related compounds. IV. Essential features for insecticidal activity in chrysanthemates and related cyclopropane esters. *Pesticide Science* **2**, 115–118.

A range of 5-benzyl-3-furylmethyl cyclopropane carboxylates and other esters are evaluated against houseflies, mustard beetles and two mosquito species. The results show the importance for activity of a *gem*-dimethyl group on the cyclopropane ring and that substitutions at C_3 give wide variations in insecticidal activity and species specificity. Some of the compounds had considerable knockdown activity against houseflies, but the structural requirements for this type of action differ from those for kill.

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9.8 BURT, P. E., LORD, K. A., FORREST, Jennifer M. & GOODCHILD, R. E. (1971) The spread of topically applied pyrethrin I from the cuticle to the central nervous system of the cockroach *Periplaneta americana*. *Entomologia Experimentalis et Applicata* **14**, 255–269.

Penetration of topically applied pyrethrin I into adult male American cockroaches (*Periplaneta americana* L.) and its subsequent distribution within the insects was studied microchemically and biologically. After applying an LD95 (0·5 μg per insect), pyrethrin I was lost from the surface of the insects at a rate diminishing with time; 20% of the dose applied penetrated during the first hour, but elimination limited the amount found inside the insects to a maximum of 13%.

Pyrethrin I sorbed on cockroach solids from aqueous solution at equilibrium is distributed between solids and solution in the ratio $3 \times 10^4 : 1$. This ratio would give a concentration of only $4 \times 10^{-11} M$ of pyrethrin I in the haemolymph of insects poisoned with 0·5 μg of the insecticide, but solids in the haemolymph would increase its pyrethrin I content and speed the spread of the insecticide from cuticle to nervous system. Chemical tests able to detect pyrethrin I at concentrations of $2 \times 10^{-8} M$ failed to show its presence in the haemolymph of poisoned cockroaches, but the haemolymph caused symptoms resembling those of pyrethroid poisoning when applied to nerve preparations from normal cockroaches.

Although pyrethrin I at $4 \times 10^{-11} M$ in the haemolymph of cockroaches seems too dilute to have produced the symptoms observed in their nervous systems, additional tests gave no evidence that the insecticide reached the nervous system by spreading over the cuticle and through the tracheal system. Larger concentrations of pyrethrin I occurring locally in the haemolymph near the nervous system during the early stages of poisoning may explain the anomaly.

9.9 EL BASHIR, E. S. (1971) Resistance to organophosphorus insecticides in the SKA strain of houseflies (*Musca domestica* L.). *Entomologia Experimentalis et Applicata* **14**, 3, 365–376.

The resistance of the diazinon selected strain of houseflies, the SKA strain, to 20 organophosphorus insecticides measured by topical application and injection, and the response of the strain to the insecticides with candidate synergists are described.

The SKA strain was very resistant to diazinon, 'ethyl Chlorthion', 'Chlorthion' and parathion, moderately resistant to five more, and only slightly resistant to the remainder. It was more resistant to the diethoxy than dimethoxy compounds and was only very slightly resistant to malathion. The compounds, expecially the phosphates, were more toxic when injected than when applied topically. Additives or substitutions in the phenyl ring of the parathion molecule resulted in compounds less toxic than parathion.

The additives piperonyl butoxide and tributyl phosphorotrithioate were inactive with many compounds and synergised or antagonized the same compounds against susceptible and SKA flies. Trio-*o*-cresyl phosphate greatly antagonized ethyl malathion and malathion.

9.10 ELLIOTT, M., JANES, N. F., (KIMMEL, E. C. & CASIDA, J. E.) (1971) Mammalian metabolites of pyrethroids. In: *Symposium*: *Chemistry and activity of insecticides of plant origin, 2nd International Congress of Pesticide Chemistry, Israel, February 1971.*

The structures of metabolites formed by rats from pyrethroids were determined by nuclear magnetic resonance and mass spectroscopy using tritium-labelled esters to assist isolation and purification.

In all metabolites isolated a carboxyl group replaces the *trans*-methyl or -methoxycarbonyl group of the acidic side chain.

The *cis*-pentadienyl side chains of pyrethrins I and II are converted to a *cis*-pent-2-enyl-4,5-diol group, to a *trans*-pent-3-enyl-2,5-diol group, or to an ester of the 4,5-diol with an aromatic acid at the 4-hydroxy group. No hydrolysis of the cyclopropane ester link is detected.

The allylic side chain of allethrin is oxidised either to a 2,3-diol or to a l-hydroxy-prop-2-enyl group. In another metabolite one methyl group on the cyclopropane ring is hydroxylated with the alcohol moiety unchanged. Some hydrolysis of the cyclopropane ester in allethrin is detected.

The susceptibility of pyrethroids to such oxidative attacks is probably related to their small toxicity to mammals.

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9.11 ELLIOTT, M., JANES, N. F. & PEARSON, B. C. (1971) The pyrethrins and related compounds. XIII. Insecticidal methyl-, alkenyl- and benzyl-substituted furfuryl and furylmethyl chrysanthemates. *Pesticide Science* **2**, 243–248.

3-Furylmethyl and furfuryl chrysanthemates with methyl, benzyl, substituted benzyl and alkenyl substituents, and other heterocyclic analogues of these compounds, are synthesised for structure-insecticidal activity investigations.

9.12 FARNHAM, A. W. (1971) Changes in cross-resistance patterns of houseflies selected with natural pyrethrins or resmethrin (5-benzyl-3-furylmethyl (±)-*cis-trans*-chrysanthemate). *Pesticide Science* **2**, 138–143.

A pyrethrins-resistant strain of houseflies, 213ab, previously selected with a 1 : 10 (by wt) mixture of natural pyrethrins and piperonyl butoxide, was further selected either with natural pyrethrins alone (strain NPR) or with resmethrin (strain 104). After 50 generations the two populations differed in their resistance to the natural and synthetic esters. Both were resistant to all pyrethroids. Part of strain NPR was immune and very much more resistant than strain 104 to the natural pyrethrins and allethrin, but it was only 2–3 times more resistant than strain 104 against the new synthetic esters resmethrin (5-benzyl-3-furylmethyl (±)-*cis-trans*-chrysanthemate), bio-resmethrin (5-benzyl-3-furylmethyl(+)-*trans*-chrysanthemate), pyresmethrin (5-benzyl-3-furylmethyl pyrethrate) and 5B2Me3FC (5-benzyl-2-methyl-3-furylmethyl (±)-*cis-trans*-chrysanthemate). Pretreatment of both strains with sesamex diminished but did not eliminate resistance. Synergism was greater in strain NPR, especially with natural pyrethrins and allethrin. Both strains had great resistance to DDT indicating that resistance to DDT and pyrethroids is linked.

Differences in resistance to different compounds suggest that at least three factors can confer resistance, one of which, *pen*, delays penetration and two others involve detoxication, one, *py a*, on the acid side of the ester linkage and the other, *py b*, on the alcohol side. Natural pyrethrins and resmethrin select for different groupings of these factors. Treatment with resmethrin does not select for *py b* presumably because this mechanism cannot attack the resmethrin molecule. Similarly when piperonyl butoxide is added to the natural pyrethrins *py b* is inhibited and so removed from selection pressure. Under these conditions, the strain produced contains the same factors as one selected by resmethrin and so shows the same small resistance to natural pyrethrins alone.

9.13 LEWIS, J. B. & SAWICKI, R. M. (1972) Characterisation of the resistance mechanisms to diazinon, parathion and diazoxon in the organophosphorus-resistant SKA strain of houseflies (*Musca domestica* L.). *Pesticide Biochemistry & Physiology*. (In the press.)

Subcellular fractions of houseflies susceptible and resistant to organophosphorus insecticides were examined to characterize *in vitro* the mechanisms of resistance to diazinon, parathion and diazoxon controlled by genes on the II and V chromosomes, using radio-labelled insecticides. The microsomal fractions of all the strains cleaved parathion and diazinon to diethyl phosphorothioic acid (DEPTA), and converted the phosphorothionate insecticides in the corresponding phosphates, in the presence of NADPH and oxygen. This conversion system, stimulated by added GSH and inhibited by sesamex, is a mixed-function oxygenase and occurred equally in susceptible and resistant houseflies. Resistant houseflies also had the following breakdown mechanisms: in the microsomal fraction 1/ a mixed-function oxygenase, easily inhibited by sesamex, which converts diazoxon, and possibly diazinon, into three unidentified metabolites, but is inactive with parathion or paraoxon. It is controlled by factor *Ses* on chromosome V; 2/ a phosphatase, controlled by gene *a* on chromosome II, which hydrolyses diazoxon and paraoxon into diethyl phosphoric acid (DEPA) in the absence of oxygen and NADPH. The resistance mechanism in the soluble fraction is a glutathione-*S*-transferase that desethylates diazinon, parathion and diazoxon into their corresponding desethyl derivatives with the concommitant formation of *S*-ethyl glutathione. This GSH-dependent system is unaffected by sesamex, lack of oxygen or NADPH, and is controlled by a factor on chromosome II.

The importance of these mechanisms on the resistance to organophosphorus insecticides is discussed.

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9.14 LORD, K. A., JEFFS, K. A. & (TUPPEN, R. J.) (1971) Retention and distribution of dry powder and liquid formulations of insecticides and fungicides on commercially dressed cereal seed. *Pesticide Science* **2**, 49–55.

Analysis of samples of seeds, mostly wheat, treated commercially with insecticides and fungicides showed that many carried much less than the theoretical dose, some less than one-tenth.

The average loadings of seeds treated with dry powder formulations were nearly always small, but the distribution of insecticide between seeds treated was fairly uniform. The average loadings of seeds treated with liquid formulations was closer to the target, but the distribution was irregular, most of the seeds carrying little insecticide and a few seeds amounts large enough to be phytotoxic.

Insecticides applied as dry powders do not adhere strongly to the seeds, but they remain in association with seeds contained and carried in bags. Applied as liquids, insecticides are difficult to remove from seeds. The ratio of insecticide to fungicide on seeds dressed with powders containing both usually resembled the ratio in the original powder. With liquid seed dressings of insecticide and fungicide applied separately in different formulations, the ratio of insecticide to fungicide often differed widely from the theoretical. The average loading of fungicide was close to the target, but the average amount of insecticide was often much less.

With either wet or dry dressings, the amount of pesticide on seeds was consistently greater from some merchants than from others. This was independent of the machinery used. Loadings were not consistently affected by type of seed-dressing machinery or formulation, stage of operation, weather or variety of seed.

9.15 (MACHIN, A. F., QUICK, M. P.) & JANES, N. F. (1971) 2-Acetyl-6-methyl-4-pyrimidinyl diethyl phosphorothionate—A new degradation product of diazinon. *Chemistry and Industry* 1198–1199.

A new compound formed by ultraviolet irradiation of diazinon was isolated, and its structure established by nmr and mass spectroscopy. It is formed by oxidation of the isopropyl group in diazinon to an acetyl group.

9.16 MCINTOSH, A. H. (1971) Control of common scab of potato. *Proceedings of the 6th British Insecticide and Fungicide Conference (1971)* **1**, 215–218.

Incidence of potato common scab, caused by soil-borne *Streptomyces scabies*, can be decreased by applying chemicals to soil. One such chemical is quintozene, which is now suspected of being carcinogenic. About 120 other chemicals were tested, using potted plants grown in the glasshouse. Most of them, at 50 ppm in soil, either failed to affect scab, or seriously decreased yield of tubers, or both.

Those which decreased scab without greatly affecting yield were, in order of increasing effectiveness: 2,5-dimethyl-3-furanilide ('BAS 3191F'; proposed common name: furcarbanil); (2,4,5-trichlorophenyl) sulphonylmethyl thiocyanate ('PH 50–82'); 2-pyridine-thiol-1-oxide, Na salt; dinocap phenols ('MC 2810'); quintozene; and captafol.

In a field trial at Woburn, Beds., quintozene and captafol, each at 70 lb/acre (78 kg/ha), were equally effective. Thus captafol may be a suitable substitute for quintozene.

9.17 MCINTOSH, A. H. (1971) Tests of aryltin compounds as potato blight fungicides. *Annals of Applied Biology* **69**, 43–46.

Triphenyl(phenylthio)tin and triphenyl(*p*-chlorophenylthio)tin were as effective as fentin acetate in controlling potato blight (*Phytophthora infestans*) in laboratory tests on detached leaflets. Diphenyltin dichloride and bis(triphenyltin)sulphide were moderately effective. Dibenzyltin and some diphenyltin compounds were ineffective.

A small change in the bioassay conditions, bringing them slightly closer to field conditions, increased the relative effectiveness of bis(triphenyltin)sulphide, making it about one-quarter as effective as fentin acetate; however, the change did not increase the relative effectiveness of triphenyl(phenylthio)tin or dibutyltin diacetate.

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9.18 (NASIM, A. I., BAIG, M. M. H.) & LORD, K. A. (1971) Chlorinated insecticide residues found in soil near Dacca, East Pakistan. *Environmental Pollution* **2**, 7–12.

Six soil samples from three different localities near Dacca were examined by silica-loaded paper and gas chromatography. All were contaminated with organochlorine insecticides and contained 1–3 ppm DDT. In addition three of them contained 0·1–0·5 ppm gamma-BHC, and the three others about 0·5 ppm dieldrin. The insecticides are readily extracted by water from the soil.

9.19 PHILLIPS, F. T. (1971) Persistence of organochlorine insecticides on different substrates under different environmental conditions I. The rates of loss of dieldrin and aldrin by volatilisation from glass surfaces. *Pesticide Science* **2**, 225–266.

A spraying apparatus to deposit radioactive insecticide evenly, and a heated wind tunnel to simulate tropical conditions, are described.

The rates at which crystals of ^{36}Cl-dieldrin and aldrin volatilised from glass surfaces were greatly influenced by temperature and wind speed (especially the former) but only slightly by humidity or crystal size. These loss rates followed single (sometimes double) exponential curves or logistic (simple sigmoid) curves.

9.20 PHILLIPS, F. T. & KAVADIA, V. S. (1972) The movement of dieldrin in young cotton plants. *International Symposium on the use of isotopes and radiation in agriculture and animal husbandry research 29 November–2 December 1971.* Nuclear Research Laboratory, Indian Agricultural Research Institute, New Delhi. (In the press.)

Dieldrin (HEOD) was taken up from aqueous suspensions via the roots of young cotton plants and transported to the stems and leaves. The uptake was probably controlled by the transpiration rate.

Dieldrin moved from 'spray' droplets on the upper cotton leaves: at least one-fifth of the applied dieldrin moved laterally over distances of 8 mm within 4 days, but penetration from the upper to lower surfaces of leaves took several weeks and apparently depended on the thickness of the cuticular layers of the leaves.

9.21 (SCOTT, T. A.) & DEVONSHIRE, A. L. (1971) The incorporation of [$^{14}C_4$] aspartic acid into nicotinic acid N-glucoside in *Nicotiana tabacum*. *Biochemical Journal* **124**, 949–950.

Nicotinic acid is incorporated into its N-glucoside in *N. tabacum*. More glucoside (about 20 ×) is present than free nicotinic acid. When [$^{14}C_4$] aspartic acid is absorbed by roots of *N. tabacum*, it is incorporated into nicotinic acid N-glucoside with virtually all the radioactivity in the carboxy group.

Entomology Department

BOOK

10.1 EDWARDS, C. A. & LOFTY, J. R. (1972) *The biology of earthworms.* London: Chapman and Hall, 283 pp.

GENERAL PAPERS

10.2 EDWARDS, C. A. (1972) Soil types and pest control. *Soil Survey Technical Monograph. Soil Type and Land Capability.* (In the press.)

10.3 EDWARDS, C. A. & THOMPSON, A. R. (1972) Pesticides and the soil fauna. *Residue Reviews.* (In the press.)

10.4 JONES, M. G. (1971) The food of Wheat Bulb flies (*Leptohylemyia coarctata* Fall.). *Proceedings of the 13th International Congress of Entomology, Moscow, 1968.* **2**, 342–343.

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10.5 TAYLOR, L. R. (1971) Aggregation as a species characteristic. *Statistical Ecology* **1**, 357–377.

PAPERS IN ROTHAMSTED REPORT, PART 2

10.6 BARDNER, R., CALAM, D. H., GREENWAY, A. E. GRIFFITHS, D. C., JONES, M. G., LOFTY, J. R., SCOTT, G. C., WILDING, N. (1972) Wheat Bulb fly. *Rothamsted Experimental Station. Report for 1971*, Part 2, 164–174.

Recent research on the Wheat Bulb fly at Rothamsted is reviewed. It is concerned with how infestations cause loss of yield, control of the pest by insecticides, and the ecology of all stages of the life cycle. Possibilities for developing new methods of forecasting and controlling the effects of infestations are discussed.

10.7 TAYLOR, L. R. & FRENCH, R. A. (1972) Rothamsted insect survey. *Rothamsted Experimental Station. Report for 1971*, Part 2, 181–199.

Tables are given of four-week samples of 33 aphid species, or species groups, from 14 sites in Great Britain and Holland during the period 13 April to 4 November 1971 and annual totals of 31 species of Macrolepidoptera at 62 sites in 1969 and 68 sites in 1970.

RESEARCH PAPERS

10.8 BARDNER, H., EDWARDS, C. A., ARNOLD, M. K. & (ROGERSON, J. P.) (1971) The symptoms of attack by swede midge (*Contarinia nasturtii*) and effects on the yield of swedes. *Entomologia Experimentalis et Applicata* **14**, 223–233.

Four experiments in S.E. England (1960–63) and one in N.E. England (1963) used different methods to expose selectively plants to swede midge infestations in the field. The two methods that satisfactorily assessed yield losses were: (1) marking naturally infested plants; (2) marking artificially infested plants with small temporary cages to confine the ovipositing midges over the plants and comparing the yields with those of nearby uninfested plants.

The symptoms of attack were recorded and classified as primary or secondary. The primary symptoms, 'swollen petiole' and 'crumple leaf', were commoner and more reliable indicators of attack than the secondary symptoms, 'many neck' and 'cabbage top', which could be caused in other ways.

Sowing date and tolerance to attack were related. Early sown plants yielded more and were more tolerant to attack than late sown plants, even when heavily attacked. It seems that only in unfavourable growing seasons would this pest seriously affect yields of swedes.

10.9 (BROWN, E. S.) & TAYLOR, L. R. (1971) Lunar cycles in the distribution and abundance of airborne insects in the Equatorial Highlands of East Africa. *Journal of Animal Ecology* **40**, 467–779.

The aerial density of moths in two years and of all insects in one year were measured at 5 ft (1·52 m) and 50 ft (15·24 m) or 30 ft (9.14 m) at Muguga in Kenya, and the results analysed in relation to the lunar cycle. Neither the total number of insects in the air, nor the aerial density at the two heights, showed any significant lunar cycle.

The vertical distribution of total flying insects had a significant lunar cycle, out of phase with the moon, insects flying higher during the first quarter than the third. The densities of total moths at both heights and the total number in flight had significant lunar cycles in one year, but not in the other, such that maxima occurred at new full moon and minima at first and third quarters. Different species had different lunar cycles of aerial density at 5 ft (1·52 m). There was no significant lunar cycle of the vertical disposition of moths in either year.

Amplitude of established cycles was always small. The density gradients are similar to those found in southern England. Lunar cycles of catches of moths at light at Muguga are not adequately accounted for by these results.

10.10 EDWARDS, C. A. & LOFTY, J. R. (1971) Nematicides and the soil fauna. *Proceedings of the 6th British Insecticide and Fungicide Conference (1971)* **1**, 158–166.

Aldicarb, methomyl and dazomet applied to soil killed half or more of the soil-inhabiting invertebrates. Only dazomet affected earthworm populations. Predatory mite populations recovered

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from the effects of the chemicals sooner than those of other mites. None of the nematicides affected insects other than Collembola.

10.11 JONES, M. G. (1971) Observations on changes in the female reproductive system of the Wheat Bulb fly *Leptohylemyia coarctata* (Fall.). *Bulletin of Entomological Research* **61**, 55–68.

In *Leptohylemyia coarctata* (Fall.) the germarium cuts off oocytes that develop through the stages 00 and 0 and I–V, recognised in other cyclorraphous flies, in 4–5 weeks. All eggs of one batch of the gonadotrophic cycle ripen at the same time. After oviposition, the split intima, the remains of the follicular epithelium, and the nurse cells slowly contract to form the follicular relic. Flies swept from winter wheat during June and July and caught in water traps in July and August showed all stages of egg development. In 1970, 24·7% of the females swept from the crop had completed the first, 4·7% the second and 0·4% the third gonadotrophic cycle. All the eggs were not laid at the same time. During the later gonadotrophic cycles, some ovarioles were non-functional. Flies laid one or two batches of eggs, rarely three. In 1970, many flies were attacked and killed by *E. muscae*. Only one out of 115 newly emerged female Wheat Bulb flies presented with foods usually found in the crop, or citrated blood, contained mature eggs after 24–27 days in small cages. Those fed only on 0·1*M* glucose survived but did not deposit yolk in the ovum; those provided only with yeast paste died. Honeydew from cereal aphids was the main source of sugar. Water in droplets and space to move seem necessary for the eggs to mature.

10.12 MACAULAY, E. D. M. (1972) A simple insect flight recorder. *Entomologia Experimentalis et Applicata* **15**, 252–254.

An apparatus is described by which flight activity of individual insects in small cages can be continuously monitored. No complicated electronic circuitry is involved, the equipment is stable and can be left unattended for long periods.

10.13 (REICHLE, D. E., CROSSLEY, D. A.), EDWARDS, C. A., & (MCBRAYER, J. F.) (1972) The impact of earthworms on the uptake, turnover and distribution of Cesium-137 in *Liriodendron* forest soil. *Proceedings of the 3rd Symposium of Radioecology, Oak Ridge, Tennessee.* (In the press.)

Studies on the dynamics of ^{137}Cs in *Liriodendron* forest ecosystems show the organo-mineral soil complex to be a major repository for ^{137}Cs. Soil slowly exchanges ^{137}Cs with other components of the ecosystem. Earthworms (primarily *Octolasium*) exceed 80% of the soil invertebrate biomass, and significantly affect the breakdown of organic matter and the accompanying release of bound elements. Seasonal analyses of the abundance and biomass of earthworms enabled total ^{137}Cs to be partitioned between earthworm tissue, soil organic and mineral-bound fractions. Information was also obtained on efficiencies of ^{137}Cs assimilation by earthworms from mineral soil and organic matter, and the turnover of ^{137}Cs in their bodies. From this a model was developed that describes the seasonal incorporation of litter and hence ^{137}Cs into soil by the earthworm population.

10.14 STEPHENSON, J. W. (1972) Gelatin as a carrier for S²-Cyanoethyl N-[(methylcarbamoyl)oxy] thioacetimidate, an experimental molluscicide. *Pesticide Science* **3**, 1–7.

Gelatin and gelatin hardened by formaldehyde, were immersed in water or exposed out of doors on bare soil, and their stability assessed. The water-soluble, protein-rich, constituents of wheat bran are palatable to slugs and can be used as an arrestant. Hardened gelatin made with aqueous wheat bran extract containing the pesticide did not disintegrate in wet weather and continued to kill slugs over a long period.

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Bee Department

General Papers

11.1 Bailey, L. (1971) The safety of pest–insect pathogens for beneficial insects. In: *Microbial control of insects and mites.* Eds. H. D. Burges & N. W. Hussey. London: Academic Press, Chapter 23, pp. 491–505.

11.2 Bailey, L. (1971) Honey-bee viruses. *Science Progress* (*Oxford*) **59**, 309–323.

11.3 Bailey, L. (1971) Honeybee paralysis; retrospect and prospect. *Report of the Central Association of the British Bee-Keepers' Association*, pp. 1–8.

Paper in Rothamsted Report, Part 2

11.4 Bardner, R., Calam, D. H., Greenway, A. E., Griffiths, D. C., Jones, M. G., Lofty, J. R., Scott, G. C. & Wilding, N. (1972) The Wheat Bulb fly. *Rothamsted Experimental Station. Report for 1971*, Part 2, 164–174.

Research Papers

11.5 Butler, C. G. (1971) The mating behaviour of the honeybee (*Apis mellifera* L.). *Journal of Entomology* (*A*) **46**, 1–11.

Stimulated by the odour of a queen's sex attractant, 9-oxodecenoic acid, drones fly upwind looking for her. This acid is produced in her mandibular glands but some becomes distributed on her body. Stimulated drones fly to any queen they see and examine her more intensely when she has another unidentified pheromone on her body, than when she has not or has 9-oxodecenoic acid only. Seizing of the queen and copulation both seem to be stimulated, not only by 9-oxodecenoic acid and an open sting-chamber, but also by unidentified material on her abdominal tergites. The same pheromone(s) that stimulates drones to examine a queen closely may also stimulate them to attempt to copulate.

11.6 Free, J. B. (1970) Effect of flower shapes and nectar guides on the behaviour of foraging honeybees. *Behaviour* **37**, 269–285.

Honeybees were trained to collect syrup from coloured discs and then presented with a choice of 'model' flowers. The colour of a model was important, but its scent even more. A foreign odour made the models less attractive than no odour. The size of a training model did not influence the size of model later chosen, but the bees preferred radially symmetrical to bilateraly symmetrical models, and models with a disruptive outline to circular models, even though trained to circular ones. Adding nectar guides to a model increased its attractiveness; dotted lines were more attractive than a black circle in the centre of a model. A disruptive outline also increased attractiveness, and its effects and those of nectar guide lines were additive. However, a limit was soon reached when more guide lines or segmentation failed to increase attractiveness. Nectar guide lines directed bees only after they had learned to seek food at a particular site in relation to them. Untrained bees were attracted to a black central area, and still more after training.

11.7 Free, J. B. (1971) Stimuli eliciting mating behaviour of bumblebee (*Bombus pratorum* L.) males. *Behaviour* **40**, 55–61.

Males were attracted to queens presented near a 'visiting place', but usually ignored those offered elsewhere along a flight route. A black object the size of a queen elicited inspection and attempts to mate; the orange and yellow bands on a queen's body and her movements seemed not to do so. The odour of a queen is important in inducing mating and odour difference probably accounted for young queens being more attractive than old ones.

11.8 Free, J. B. & Williams, I. H. (1970) Exposure of the Nasanov gland by honeybees (*Apis mellifera*) collecting water. *Behaviour* **37**, 286–290.

When worker honeybees have made several consecutive trips for water many of them expose their Nasanov glands at the source of supply, and especially when it lacks an odour of its own.

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The tendency of bees to expose their Nasanov glands when collecting sugar syrup or abnormally abundant supplies of nectar seems an adaptation of the behaviour that naturally occurs when collecting water.

11.9 FREE, J. B. & WILLIAMS, I. H. (1971) Effect of giving pollen and pollen supplement to honeybee colonies on the amount of pollen collected. *Journal of Apicultural Research* **10**, 87–90.

Feeding pollen in the hive in summer decreased the amount of pollen collected by the colony. But when a pollen supplement was provided instead, little was consumed and there was no apparent effect on pollen collection.

11.10 (PANKIW, P.), BAILEY, L., (GOCHNAUER, T. A. & HAMILTON, M. A.) (1970) Disinfection of honeybee combs by gamma irradiation. II. European foul brood disease. *Journal of Apicultural Research* **9**, 165–168.

After exposing combs from honeybee colonies with European foul brood to gamma irradiation, up to 0·8 Mrad, they still contained many viable cells of *Streptococcus pluton* and of *Bacillus alvei*, and caused European foul brood when placed in healthy colonies.

11.11 SIMPSON, J. (1970) The male genitalia of *Apis dorsata* (F.) (Hymenoptera : Apidae). *Proceedings of the Royal Entomological Society of London* (*A*) **45**, 169–171.

The everted aedeagus of *Apis dorsata* is described, and compared with that of *A. mellifera* and *A. cerana*.

11.12 SIMPSON, J. & MOXLEY, E. (1971) The swarming behaviour of honeybee colonies kept in small hives and allowed to outgrow them. *Journal of Apicultural Research* **10**, 109–113.

Colonies that outgrew small hives swarmed only when they had occupied queen cells and always with old queens. Their behaviour thus differed from that recorded from colonies with abundant hive space, which swarmed with young queens (after the old ones were dead), and also from the behaviour recorded from colonies suddenly put into small hives, which swarmed without occupied queen cells.

11.13 SPRADBERY, J. P. (1971) Seasonal changes in the population structure of wasp colonies (Hymenoptera : Vespidae). *Journal of Animal Ecology* **40**, 501–523.

Seasonal changes in the population structure of 89 colonies of wasps (*Vespula vulgaris* and *V. germanica*) collected near Harpenden, Hertfordshire, in 1961 are described.

11.14 WILDING, N. (1972) Conidial discharge of *Entomophthora thaxteriana* Petch from the pea aphid *Acyrthrosiphon pisum* Harris. *Journal of General Microbiology* **69**, 417–422.

At 21°, conidia of *Entomophthora thaxteriana* were first discharged from infected pea aphids about 6–9 hours after the aphids died and the discharge was fastest about nine hours later. In constant light, the rate then slowed and discharge ended about 16 hours after an infected aphid died; in constant darkness the fastest rate (2×10^3 conidia/h/aphid) was only one quarter that in constant light but it was maintained for 10 hours. In alternating 12 hours light, 12 hours darkness, the rate of conidial discharge much increased two hours after the admission of light and much diminished two hours after light was excluded. In constant light, the average number of conidia discharged from one adult apterous aphid was at least 10^5, twice that in constant darkness. Discharge of conidia began earliest at 20° but the discharge was fastest at 25°. Ultimately, similar numbers of conidia were discharged at any temperature from 5° to 25°C; conidia were not discharged at 0° or 30°C.

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Statistics Department

General Papers

12.1 Nelder, J. A. (1972) Mathematics for biologists. *Bulletin of the Institute of Mathematics and its Applications.* (In the press.)

12.2 Nelder, J. A. (1972) Summary and assessment: A statistician's point of view. In: *Mathematical models in ecology.* London: Blackwell's Scientific Publications. (In the press.)

Research Papers

12.3 Boyd, D. A., (Williams, J. H. & Forbes, N.) (1972) Tests of long-term residues of phosphorus fertilisers. *Experimental Husbandry.* (In the press.)

The residual value of two amounts of four forms of phosphorus fertiliser given between 1951 and 1964 were evaluated by test dressings of four amounts of superphosphate in four experiments in 1967, two with potatoes and two with kale; one of the kale experiments was damaged by pigeons and the results are of doubtful value.

On a site fairly rich in P at High Mowthorpe there were only small responses both to 'new' P and to residues. At Rosemaund and Trawscoed, by contrast, residues alone increased yield more than 50%, and there were large effects of 'new' P; with fresh dressings residues had little effect. In terms of fresh dressings, residues were equal to about 4% of the original dressings.

The apparent value of residues depends very much on how the fresh dressings are given; to standardise the method and so make results of future experiments as comparable as possible from site to site and from crop to crop, the test dressings should be broadcast on the plough furrow and thoroughly worked into the seed bed.

The risk of bias and the need for proper estimates of plot error when tests are made on the sites of former long-term experiments are discussed.

12.4 Draycott, A. P., Durrant, M. J. & Boyd, D. A. (1971) The relationship between soil phosphorus and response by sugar beet to phosphate fertiliser on mineral soils. *Journal of Agricultural Science (Cambridge)* **77**, 117–121.

(For summary see No. 16.26.)

12.5 Gower, J. C. (1972) Classification criteria and algorithms. *Computer Journal.* (In the press.)

Some points raised by the axiomatic approach to classification are discussed and an attempt is made to clarify the role played by criteria in the theoretical definitions of optimal classes and their place in computing algorithms. The importance of understanding the purposes of classification, and the different problems raised by different classes of things to be classified, are stressed.

12.6 Gower, J. C. & (Barnett, J. A.) (1971) Selecting tests in diagnostic keys with unknown responses. *Nature, London* **232**, 491–493.

A method is discussed for constructing diagnostic keys to distinguish between n types by examining some subset of v characters. For each type the characters are present, absent or unknown. The method is intended to give an approximation to the key with the smallest average number of steps to identification, but a simple modification is described that gives a sub-optimum key but uses fewer characters.

12.7 (James, A. T.) & Wilkinson, G. N. (1971) Factorisation of the residual operator and canonical decomposition of nonorthogonal factors in the analysis of variance. *Biometrika* **58**, 279–294.

A factorisation is given of the residual operator for nonorthogonal analysis of variance. It is interpreted geometrically in terms of the critical angles between the subspaces determined by the factors. The factorisation determines a recursive procedure for analysis. Canonical components

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are defined and a method of computing them is given together with formulae for their variances, because these would be required for combining information, as for instance, in the recovery of interblock information.

12.8 KRZANOWSKI, W. J. (1971) A comparison of some distance measures applicable to multinomial data, using a rotational fit technique. *Biometrics* **27**, 1062–1068.

The problem of devising a suitable measure of distance between populations on the basis of discrete variables has attracted some attention. Some of the more common measures are compared.

12.9 KRZANOWSKI, W. J. (1972) Techniques in multivariate analysis. *Eucarpia.* (In the press.)

The need for multivariate analysis arises whenever more than one characteristic is measured on several individuals, and relationships among the characteristics make it necessary for them to be studied simultaneously. A simple geometrical model is often used to study any inter-relationships that may exist among the individuals. An individual that has p characteristics measured on it may be represented as a point in p-dimensional space; its coordinate on the jth orthogonal axis is given by the measurement on the jth characteristic. When $p > 2$, such a representation may give rise to difficulties of visualisation and interpretation. The paper surveys a class of techniques developed to lessen dimensionality in multivariate situations, while retaining detail enough to represent the data adequately.

12.10 KRZANOWSKI, W. J. & NEWMAN, A. C. D. (1972) A computer simulation of cation distribution in the octahedral layers of micas. *Mineralogical Magazine.* (In the press.)

Without direct evidence that cations favour particular sites in the octahedral layers of phlogopite–biotite micas, it is usually assumed they are distributed randomly. Such a distribution, however, implies appreciable populations of cation combinations that seem electrostatically improbable. A computer program was written that rearranges a random distribution so that the improbable combinations of cations are eliminated by predetermined restrictions. Conditions deduced from Pauling's electrostatic valence rules lead to grouping of trivalent cations around vacancies; for some chemical compositions, chains of alternate trivalent cations and vacancies extend through the structure.

12.11 LEECH, F. B. (1971) A critique of the methods and results of the British national surveys of disease in farm animals. *British Veterinary Journal* **127**, 511–522, and 587–592.

Part I. Discussion of the surveys

A critical discussion of the British national surveys of disease in farm animals, with conclusions related to the experiences of these surveys.

Part II. Some general remarks on population surveys of farm animal disease

A discussion of the five British national surveys in Part I of this paper suggested some general conclusions about planning such surveys that are discussed in this part.

12.12 NELDER, J. A. & GOWER, J. C. (1972) Statistical systems and general-purpose languages. *Bulletin of the International Statistical Institute.* (In the press.)

We distinguish *packages*, driven by a main program in the same programming language, and *systems*, which have their own language.

The package is flexible but the restricted operands in existing programming languages make data-handling difficult. Systems are better at data-handling but may be otherwise inflexible.

Some of the requirements are given for a good general-purpose language that would largely obviate the need for constructing special system languages. The extent to which ALGOL 68 meets these requirements is discussed.

Problem-oriented languages may survive but their implementation can be greatly simplified by a good general-purpose language.

The structure-defining properties of the new languages make standardisation of data-structures

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essential if programs are to be transferable. Statisticians should develop standards and ensure that new languages have the facilities they need.

12.13 Ross, G. J. S. (1972) Stochastic model fitting by evolutionary operation. In: *Mathematical models in ecology*. London: Blackwell's Scientific Publications. (In the press.)

When an observed distribution or curve is assumed to arise from a stochastic model it is often not possible to obtain explicit expressions for the predicted values corresponding to given parameters. However, simulation experiments using pseudo-random numbers can be used to obtain approximations to the likelihood function, the variance of the estimated likelihood depending on the number of trials used. Hence approximate maximum likelihood estimates and confidence regions for the parameters can be obtained by applying evolutionary operation to the approximate likelihood function.

12.14 WILKINSON, G. N. & ROGERS, C. E. (1972) Symbolic description of factorial models for analysis of variance. *Applied Statistics*. (In the press.)

The paper describes the symbolic notation and syntax for specifying factorial models for analysis of variance in the control language of the GENSTAT 5 statistical program system at Rothamsted. The notation generalises the structure-formulae described by Nelder. A further extension of the syntax is discussed for specifying models generally (including non-linear forms).

Computer Department

GENERAL PAPER

13.1 (DAVIDSON, J. N.) with appendices by YATES, F. & (MCCREA, W. H.) (1971) William Ogilvie Kermack. 1898–1970. *Biographical Memoirs of Fellows of the Royal Society* **17**, 399–429.

RESEARCH PAPERS

13.2 YATES, F. (1972) The analysis of surveys on computers—features of the Rothamsted survey program. *Applied Statistics*. (In the press.)

The steps required in the analysis of surveys on computers, and the requirements of a general program are set out and features of the latest version of the Rothamsted program, implemented on the ICL 4–70 and IBM 360–50, described.

13.3 YATES, F. (1972) The use of computers for statistical analysis: a review of aims and achievements. *Bulletin of the International Statistical Institute*. (In the press.)

The rapid increase in the power of computers and the introduction of remote access terminals and visual display provide new possibilities for the processing and analysis of statistical data and in editing and analysis. There is an imperative need for good libraries of programs suitable for users who have little knowledge of computers, including those who are inexperienced in data analysis.

13.4 YATES, F. (1972) A Monte-Carlo trial on the behaviour of the non-additivity test with non-normal data. *Biometrika* **59**. (In the press.)

The behaviour of the *t*-test based on Tukey's one degree of freedom for non-additivity with non-normal data was investigated by a small Monte-Carlo trial. As expected, the levels of significance were considerably exaggerated when there were no real additive effects and the data were skew, but there was no serious disturbance when additive effects of any magnitude were introduced. The implications of these findings in the various contexts in which the test may be used are discussed.

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Field Experiments Section

General Paper

14.1 Dyke, G. V. (1971 and 1972) What we have learned about leys. (2 parts) *Arable Farmer* December 1971, 18–20, and January 1972, 46–48.

A brief account of the Ley–Arable experiments at Rothamsted and Woburn.

Broom's Barn Experimental Station

General Papers

16.1 Draycott, A. P. (1971) Fertiliser requirement of sugar beet. In: *Sugar Beet* (Shellstar Handbook), 22–28.

16.2 Draycott, A. P. (1971) Time and form of fertiliser spreading. *West Suffolk Newspapers—Farm Supplement*, Autumn 1971, 6–7.

16.3 Draycott, A. P. & Durrant, M. J. (1971) Plant and soil magnesium in relation to response of sugar beet to magnesium application. *I.I.R.B. (Journal of the International Institute for Sugar Beet Research)* **5**, 129–135.

16.4 Draycott, A. P. & Last, P. J. (1971) How much nitrogen? *British Sugar Beet Review* **40**, 21–25.

16.5 Dunning, R. A. (1971) Docking disorder. In: *Sugar Beet, a manual for farmers* (Fisons Agrochemical Division), 43–45.

16.6 Dunning, R. A. (1971) Pests. In: *Sugar Beet* (Shellstar Handbook), 40–49.

16.7 Dunning, R. A. (1971) A survey of sugar beet pest and disease incidence and damage, and pesticide usage in Europe. *I.I.R.B. (Journal of the International Institute for Sugar Beet Research* **6**. (In the Press.)

16.8 Heathcote, G. D. (1971) Abundance of aphids and some insects that prey on them in Suffolk, as shown by catches on sticky traps. *Transactions of the Suffolk Naturalists' Society* **15**, 437–442.

16.9 Heathcote, G. D. (1971) Mangold clamps and virus yellows. *British Sugar Beet Review* **39**, 173–174.

16.10 Heathcote, G. D. (1972) Evaluating aphid populations on plants. In: *Aphid technology*. London: Academic Press, Ch. 3, 105–145.

16.11 Hull, R. (1971) Conclusions of the symposium on integrated control of pests and diseases of sugar beet. *I.I.R.B. (Journal of the International Institute for Sugar Beet Research)* **5**. (In the press.)

16.12 Hull, R. (1971) Control of aphids and yellows in sugar beet. *East Anglian Daily Press*, Sugar Industry Supplement, September 1971.

16.13 Hull, R. (1971) Diseases of sugar beet. In: *Sugar Beet* (Shellstar Handbook), 50–59.

16.14 Hull, R. (1970) The organisation and work of an experimental station devoted to research on the sugar-beet crop in Great Britain. In: *The organisation and methods of agricultural research*. Ministry of Overseas Development, 75–81.

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16.15 HULL, R. (1971) Sugar beet diseases. In: *Diseases of crop plants.* Ed. J. H. Western. London: Macmillan, Ch. 9, 160–181.

16.16 HULL, R. & DUNNING, R. A. (1972) Pests and diseases of sugar beet, fodder beet and mangolds. In: *Insecticide and fungicide handbook*, 4th edition. Ed. H. Martin. Oxford: Blackwell's Scientific Publications, Ch. 7. (In the press.)

16.17 HULL, R. & JAGGARD, K. W. (1971) Recent developments in the establishment of sugar-beet stands. *Field Crop Abstracts* **24**, 381–390.

PAPERS IN ROTHAMSTED REPORT, PART 2

16.18 DRAYCOTT, A. P., DURRANT, M. J., HULL, R. & WEBB, D. J. (1972) Yields of sugar beet and barley in contrasting crop rotations at Broom's Barn, 1965–70. *Rothamsted Experimental Station. Report for 1971*, Part 2, 149–154.

Yields of sugar beet were compared when grown in five contrasting rotations; sugar beet every year (R1); once in three years with two barley crops (R2); once in six years with five barley crops (R3); once in three years with a two-year ley (R4) and with beans and potatoes (R5). During the six years of the experiment the yields of sugar beet in all rotations did not differ significantly. Yields of barley declined from 3·3 t/ha grain in the first year to 2·7 t/ha in the third year after sugar beet but were unchanged thereafter. Giving 0, 63, 125 or 188 kg/ha N to the sugar beet showed response was similar in all rotations but differed from year to year. One hundred and twenty-five kg/ha was more than enough to give maximum sugar yield in all rotations every year; giving more neither increased nor decreased yield. The residual nitrogen from the largest dressing slightly decreased the yield of grain from the following barley but did not affect the yield of the other crops.

Comparison of the amounts of nutrients removed in the crops with the amount applied in fertiliser showed that yields were not limited by lack of nitrogen and phosphorus. Although on average of the six years, the amount of potassium applied exceeded the amount removed by all rotations, some crops may have responded to more because the residues differed greatly between rotations. The effect of increasing potassium and of giving magnesium is being investigated.

16.19 DRAYCOTT, A. P., DURRANT, M. J. & WEBB, D. J. (1972) Long-term effects of fertilisers at Broom's Barn, 1965–70. *Rothamsted Experimental Station. Report for 1971*, Part 2, 155–164.

Results are reported from the first six years of an experiment testing 18 fertiliser treatments on yield and composition of crops in a rotation of sugar beet, winter wheat and spring barley. The main object was to see whether the fertiliser recommendation (F_1 Table 2) based on many annual experiments on commercial farms was sufficient or whether larger dressings (F_2) might eventually give larger yields.

F_1 produced maximum yield of sugar during the first three years but F_2 slightly more during the second three. The recommended dressing of nitrogen gave maximum yield every year and phosphorus fertiliser was not needed by sugar beet any year. Without sodium, the double dressing of potassium was needed but with sodium (as in F_1) there was little response to potassium. It is therefore not clear why sugar beet with F_2 outyielded F_1 in the later years. Nor is it clear why FYM increased yield slightly in most years even with F_2. The cereal yields showed that F_1 sufficed for wheat but barley needed the double dressing of nitrogen.

Crops on plots without fertiliser removed about 300 kg/ha N, 60 kg/ha P and 220 kg/ha K during the six years. F_1 supplied about the same amount of each element as was taken off in crops, whereas F_2 supplied about 300 kg/ha N, 160 kg/ha P and 350 kg/ha K more than crops removed. Soil phosphorus extracted with sodium bicarbonate solution was related to, but always much less than, the amount calculated from fertiliser additions and crop offtakes. When potassium was added or small amounts removed, there was a smaller but related change in soil potassium; when more than 75 kg/ha potassium was removed, soil potassium decreased only slightly.

The experiment provides little evidence that recommendations based on annual trials need increasing. The experiment will be continued unchanged in 1971–73.

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Research Papers

16.20 Byford, W. J. (1971) Organo-mercury fungicide treatment of sugar-beet seed. *Annals of Applied Biology* **69**, 245–252.

Sugar-beet seed treated with 1% volume to weight of 1·2% ethyl mercuric phosphate (EMP) solution in the 'Misto-o-Matic' machine gave seedling emergence in the field and final plant stand comparable to EMP steep. However, when the seed was stored after treatment seedlings were sometimes damaged, and the treatment was not considered a suitable replacement for the EMP steep given to all sugar-beet seed in Britain.

16.21 Cooke, D. A. & Draycott, A. P. (1971) The effects of soil fumigation and nitrogen fertilisers on nematodes and sugar beet in sandy soils. *Annals of Applied Biology* **69**, 253–264.

In 15 experiments on light land infested with plant-parasitic nematodes, fumigating the soil during the previous winter with 'D–D' increased the average yield of sugar-beet roots from 25 to 36 t/ha; this was more than obtained with various forms of nitrogenous fertilisers used in amounts up to 250 kg N/ha. Giving 85 kg N/ha increased yields on fumigated plots by 7 t/ha, and there was little benefit from giving more. Fumigation killed 65% of *Pratylenchus* spp. 80% of *Trichodorus* spp. and 90% of *Tylenchorhynchus* spp. in the top 5 cm of the soil and, at 15–20 cm deep, 90, 93 and 95% respectively. The yield increase from fumigant at different sites was not correlated with the initial populations of nematodes. The average increase in yield from fumigation was only poorly correlated with rainfall during May. The increases in nematode populations between April and August depended on rainfall, and were positively correlated both with the accumulated rainfall for the 10 weeks before sampling the soil in August and with the rainfall during the week previous to sampling. Fumigation not only improved the health of roots, and so enabled them to use nitrogen more efficiently, but also increased the amount of available nitrogen in the soil and decreased the amount lost by leaching. Injected anhydrous ammonia did not affect the populations of nematodes.

16.22 Draycott, A. P. (1970) Anhydrous ammonia compared with solid fertiliser for sugar beet. *Anhydrous ammonia: Proceedings of a symposium on aspects of its technology and use as a fertiliser.* National College of Agricultural Engineering, Silsoe, 15–17 December 1970. Guildford: IPC Science and Technical Press, 69–72.

Anhydrous ammonia was compared with 'Nitro-Chalk' for sugar beet in 15 experiments on farms in Eastern England and in three at Broom's Barm, on sandy loams or loamy sands on which nearly half the sugar-beet crop is grown in Great Britain. The nitrogen fertilisers supplied 166 kg/ha N on other farms and 126 kg/ha N at Broom's Barn. Various times of applying the ammonia were compared at Broom's Barn—it was injected at the end of the winter into the ploughed but otherwise uncultivated soil, in spring into the partially prepared seedbed or at the end of May as a side dressing before singling the plants. The solid fertiliser was always broadcast on the partially prepared seedbed.

On average of the 15 experiments, there was no significant difference in yield of roots, tops or sugar, or in sugar percentage or juice purity, between sugar beet given 'Nitro-Chalk' or anhydrous ammonia.

At Broom's Barn average root yields were largest with 'Nitro-Chalk' but not significantly larger than with anhydrous ammonia injected in the seedbed. With anhydrous ammonia injected as a side dressing before singling yields were always significantly less than with 'Nitro-Chalk'; with the late winter injection, they were significantly less in two out of three years. Sugar percentage was not affected significantly but it was always least with 'Nitro-Chalk'. Sugar yield was least from plots with the side-dressed anhydrous ammonia and greatest with the solid. At harvest, beet grown with anhydrous ammonia injected during winter contained 87%, with anhydrous ammonia in the seedbed 95%, and with anhydrous ammonia as a side dressing 93%, of the amount in the crop given solid fertiliser.

Yields from 'Nitro-Chalk' were slightly larger than with anhydrous ammonia, but not significantly so provided this was injected just before sowing. The poor yield when anhydrous ammonia was injected after the beet was established probably means it was applied at the wrong time.

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16.23 DRAYCOTT, A. P. (1970) The growth of sugar-beet roots in relation to moisture extraction from the soil profile. *I.I.R.B. (Journal of the International Institute for Sugar Beet Research)* **5**, 65–70.

Periodic measurements of soil moisture were made in sugar-beet crops in each of the years 1967–69. The quantity of water (g/cm^3) was determined at 5, 10, 15 and 20 cm, and at 10 cm intervals down to 100 cm, using a neutron moderation meter.

In all three years moisture was lost from the surface 20 cm mainly by evaporation from bare soil during the period up to singling. During the latter half of May and in early June, sugar-beet roots withdrew moisture down to 100 cm. In the two dry years, roots took out some moisture from below 100 cm.

By integrating the areas between sequential moisture profiles, measured soil moisture deficits were obtained. These were compared with deficits calculated from meteorological data and the results suggested that with deficits under sugar beet of less than 15 cm, the root system sustained the water requirement of the crop from soil reserves, except when the deficit increased rapidly in 1967.

16.24 DRAYCOTT, A. P. & DURRANT, M. J. (1971) Prediction of the fertiliser needs of sugar beet grown on fen peat soils. *Journal of the Science of Food and Agriculture* **22**, 295–297.

The fertiliser requirements of sugar beet grown on fen soils were tested in 52 experiments from 1963 to 1969. In some fields, N, P, K and Na and, especially N and P, greatly increased yields, but the average responses obtained with the four elements were small. To help to predict where, and how much, fertiliser is needed, soils were grouped according to soil analysis and classified by loss on ignition. Sugar beet grown on soils with less than 20 μg/ml P (extracted with sodium bicarbonate) needed 83 kg/ha P, with 21–45 μg/ml P, 41 kg/ha P and with more than 45 μg/ml P no fertiliser was required. Most soils were rich in K; with less than 100 μg/ml K (extracted with ammonium nitrate), 208 kg/ha K was probably justified; with 100–250 μg/ml, 120 kg/ha K was needed. Most of the responses to agricultural salt were by crops on soils with exchangeable sodium concentrations of less than 30 μg/ml Na. Loss on ignition was related to response to N fertiliser; when the loss was 14–25%, N increased yield by 0·76 t/ha sugar and 150 kg/ha N fertiliser was needed and when the loss was 26–35%, the yield was increased by 0·44 kg/ha and 75 kg/ha N was needed. With greater losses there was little response.

16.25 DRAYCOTT, A. P., DURRANT, M. J. & LAST, P. J. (1971) Effects of cultural practices and fertilisers on sugar beet quality. *I.I.R.B. (Journal of the International Institute for Sugar Beet Research)* **5**, 169–185.

Effects of plant population, length of growing periods (by varying the time of sowing and harvesting), irrigation, rainfall before harvest and fertilisers on sugar beet quality are summarised from 350 field experiments made between 1956 and 1969. Those testing cultural practices were made at Broom's Barn and those testing fertilisers on farms elsewhere.

Sugar percentage and juice purity increased significantly with increasing plant population every year. Effects of length of growing period were less consistent but increasing it always increased juice purity in the range tested (March—December). On average, lengthening the growing period at first increased and then decreased sugar percentage but the effect was largely governed by rainfall before harvest. Irrigation decreased sugar percentage but increased juice purity.

Of the fertilisers tested, only nitrogen changed the quality greatly, 225 kg/ha decreasing sugar percentage by 1·0% (the magnitude of the effect was similar on all soil types) and juice purity by 1·5%. Phosphate had little effect on sugar percentage and the cations potassium, sodium and magnesium increased it slightly. Neither phosphate nor the cations had much effect on juice purity.

The quality changes established were used to investigate optimum plant population, length of growing period and nitrogen dressing, for total sugar and extractable white sugar and the corresponding changes in the value of the crop. The optima were remarkably similar, suggesting that practices yielding most total sugar also give near-maximum extractable white sugar.

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16.26 DRAYCOTT, A. P., DURRANT, M. J. & BOYD, D. A. (1971) The relationship between soil phosphorus and response by sugar beet to phosphate fertiliser on mineral soils. *Journal of Agricultural Science* (*Cambridge*) **77**, 117–121.

Results of two groups of experiments testing phosphate fertiliser for sugar beet were re-examined; there were 53 experiments made between 1957 and 1960 in group 1 and 25 experiments between 1957 and 1959 in group 2. The mean response of total sugar to 126 kg/ha P_2O_5 was only 160 kg/ha but on a few fields response exceeded 1000 kg/ha. Response was greater in 1958 than in other years, but between-site variance accounted for most of the difference from year to year.

Stored soil samples were analysed for phosphorus by four methods; the results were compared and related to the yield response to phosphate fertiliser. After allowing for experimental error, the percentages of the between-sites variance of the responses accounted for by log (soil P) were (group 1 first): sodium bicarbonate, 60 and 62%; anion resin, 52 and 30%; ammonium acetate/acetic acid, 52 and 0%; and calcium chloride, 42 and 2%. When soil pH was included in the regression equation, prediction of response by anion resin much improved and equalled that of sodium bicarbonate. Ammonium acetate/acetic acid was ineffective on soils with much free calcium carbonate.

As two-thirds of the soils had sodium bicarbonate-soluble phosphorus concentrations between 15 and 45 ppm P with mean response 65 kg/ha sugar, there is only limited scope for increasing the profitability of the crop by improving P manuring. However, more P fertiliser can be recommended for the few soils with $\leqslant$ 10 ppm P and P fertiliser can be withheld from fields with more than 45 ppm. The dressings we recommend are 180, 120, 60, 30 and 0 kg/ha P_2O_5 (approximately 1·5, 1·0, 0·5, 0·25 and 0 cwt/acre P_2O_5) on soils with $\leqslant$ 10, 11–15, 16–25, 26–45 and $\geqslant$ 45 ppm sodium bicarbonate-soluble P respectively.

16.27 DRAYCOTT, A. P. & FARLEY, R. F. (1971) Effect of sodium and magnesium fertilisers and irrigation on growth, composition and yield of sugar beet. *Journal of the Science of Food and Agriculture* **22**, 559–563.

Field experiments (1968–70) were made to find how sodium and magnesium fertilisers and irrigation affect yield of surgar beet. Nil and 250 kg/ha sodium (as agricultural salt) and 0 and 100 kg/ha magnesium (as kieserite) were tested; also irrigation to prevent the calculated soil moisture deficit from exceeding 40 mm. The plants contained most sodium during August when plants not given it contained 80 kg/ha and plants given it contained 145 kg/ha. Measured losses of sodium and potassium from the soil equalled the total taken up by the crop. Sodium and irrigation increased the leaf area index and total dry matter of the crop. The average increase in sugar yield was 0·5 t/ha from sodium and 0·68 t/ha from irrigation. From late July onwards, irrigated plants had slightly fewer leaves than unirrigated ones. Plants given sodium had more of their total dry matter in the roots than those not given sodium. The effects of sodium and irrigation were additive. Magnesium fertiliser increased the concentration of magnesium in the plants and their total content, but had no effect on growth, uptake of the other cations or final yield of the crop. It is concluded that sodium increased sugar yield by increasing the leaf area index early in the season and by increasing the proportion of the total dry matter partitioned to the roots; irrigation also appeared to act partly by increasing leaf area index but it also greatly increased the uptake of nutrients.

16.28 DUNNING, R. A. (1971) Changes in sugar beet husbandry, and some effects on pests and their damage. *Proceedings of the 6th British Insecticide and Fungicide Conference* (*1971*) **1**, 1–8.

The increased use of genetic monogerm seed and herbicides during the last decade, and the introduction of 'planting-to-a-stand' are recorded for England and for several other West European countries. Some of the rapid changes in beet husbandry, especially the steady decline in the number of seeds sown/acre, increase the risk of pest damage. However, in trials in 1965, and in field observations in 1964–66, seedlings killed by pests did not increase with decline in numbers of seeds sown/acre. Some results of 1971 trials, testing the effects of different seed spacings, herbicide treatments and seedbed compactions on pest aggregation and damage are given.

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16.29 DUNNING, R. A. & WINDER, G. H. (1971) Changes in organo-chlorine usage on sugar beet, and progress in the replacement of dieldrin seed treatment. *Proceedings of the 6th British Insecticide and Fungicide Conference (1971)* **2**, 367–375.

Organo-chlorine pesticides are used on sugar beet to prevent damage by pests attacking the root, stem or foliage, especially of seedlings. Only γ-BHC or DDT are now applied to soil or foliage; the acreage treated is increasing because fewer seeds/acre are sown and growers wish to protect the seedlings from pests such as millepedes (*Blaniulus* and other species), leatherjackets (*Tipula* spp.), pygmy beetle (*Atomaria linearis*) and beet flea beetle (*Chaetocnema concinna*). Trials have not been made to find alternative materials to γ-BHC and DDT for preventing damage to foliage. Currently all seed is dressed with 0·2% of dieldrin and most is pelleted; progress has been made in testing alternative materials, of which methiocarb seems the best for control of pygmy beetle, one of the major pests of seedlings.

16.30 DUNNING, R. A. & WINDER, G. H. (1972) Some effects, especially on yield, of artificially defoliating sugar beet. *Annals of Applied Biology* **70**, 89–98.

The effects of completely defoliating sugar beet at different dates from May to October were examined in four years. In each year there were plots given the usual dressing of nitrogen fertiliser to the seedbed, and also in two of the years plots given no nitrogen.

At harvest in mid-November, minimum root weights followed defoliation in July or August, but defoliation in August or later gave minimum sugar contents. When nitrogen was applied to the seedbed sugar yields were smallest after August defoliation; without nitrogen, July defoliation gave the smallest sugar yields. Root yield was smaller but sugar content usually greater than with nitrogen. Up to 40% of the sugar yield was lost by July or August defoliation and late defoliation increased some of the impurities in the root juice. Yields, and recovery from defoliation, were greater with nitrogen than without. Partial defoliation in May had relatively little effect on yield. Defoliation affected the incidence of virus yellows differently in different years.

16.31 DURRANT, M. J. & DRAYCOTT, A. P. (1971) Uptake of magnesium and other fertiliser elements by sugar beet grown on sandy soils. *Journal of Agricultural Science (Cambridge)* **77**, 61–68.

Ten experiments (1967–69) on sandy soil in East Anglia measured the effect of magnesium fertiliser on yield and cations in sugar beet. Magnesium fertiliser increased sugar yield by up to 0·80 t/ha and on the three most responsive fields it consistently increased top and root dry-matter yields throughout the growing period.

On average, without magnesium fertiliser, the concentration of magnesium in tops progressively decreased from 0·33% at singling to 0·15% at harvest, and in roots from 0·39% to 0·09%. The corresponding decreases with magnesium fertiliser were (tops) from 0·68% to 0·20% and (roots) from 0·48% to 0·10%. Yield was increased by magnesium fertilisers when tops contained less than 0·35% Mg during May, 0·30% during June, 0·22% during July and 0·17% during August. Deficiency symptoms were not visible until the concentration in tops averaged less than 0·2%—the percentage of plants with symptoms increased rapidly at smaller concentrations. Magnesium fertiliser decreased the concentration of calcium in tops and roots but did not affect the concentration of potassium or sodium.

The maximum amount of magnesium, potassium, sodium and calcium in tops (August–September) was 11, 218, 75 and 62 kg/ha respectively; these decreased to 8, 168, 55 and 50 kg/ha at harvesting, showing that only about 75% of the largest amount in tops was present at harvest. The amounts removed in roots at harvest were 9 kg/ha Mg, 75 kg/ha K, 11 kg/ha Na and 26 kg/ha Ca. A dressing of 100 kg/ha magnesium increased the amount of magnesium in the crop at harvest by only 4·5 kg/ha.

16.32 LAST, P. J. & DRAYCOTT, A. P. (1971) Predicting the amount of nitrogen fertiliser needed for sugar beet by soil analysis. *Journal of the Science of Food and Agriculture* **22**, 215–220.

In 1961–65, soils from 65 fields were analysed for potentially available nitrogen, and field experiments were made to measure the optimum nitrogen dressing for sugar beet. The soils were

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sampled during autumn and spring and incubated either fresh or air-dry, all aerobically and some anaerobically. All were analysed for organic carbon and total nitrogen, and 35 were analysed for barium hydroxide-extractable 'glucose.'

The amount of nitrogen mineralised during incubation of fresh spring-sampled and air-dry autumn-sampled soils was significantly correlated to organic carbon and total nitrogen concentrations, also to the amount of 'glucose' extracted by barium hydroxide. Correlations were usually better with air-dry than with fresh samples, and were also better with spring than with autumn samples.

The amount of mineral nitrogen in air-dry, spring-sampled soils was moderately well related to the optimum nitrogen dressing ($r = -0{\cdot}48^{**}$) and to the increase in sugar yield from the nitrogen fertiliser ($r = -0{\cdot}49^{**}$). Although not tested on all the samples, the nitrogen mineralised during anaerobic incubation was best related ($r = -0{\cdot}84^{**}$) to the optimum nitrogen dressing. The barium hydroxide-extractable 'glucose' concentration was also significantly related to the optimum nitrogen dressing ($r = -0{\cdot}32^{*}$) and to the increase in sugar yield ($r = -0{\cdot}49^{**}$).

16.33 LONGDEN, P. C. (1971) Advanced sugar-beet seed. *Journal of Agricultural Science (Cambridge)* **77**, 43–46.

A technique is described for speeding germination of monogerm sugar-beet seed. The optimum treatment was four cycles of wetting seed with its own weight of water and storing it in a sealed container for 24 hours before drying for 48 hours. The number of cells/embryo was doubled, seedlings emerged approximately 2·5 days sooner and seedling shoot weight was increased by 31 to 53%.

16.34 LONGDEN, P. C. (1971) Monogerm sugar-beet seed production experiments. *Journal of Agricultural Science (Cambridge)*. (In the press.)

Eight experiments investigated how different sowing and harvest dates, plant populations and fertilisers affect yield, germination and size of seed from hybrid monogerm sugar-beet seed crops, grown *in situ* when raised under barley cover in Lincolnshire, or open sown in Oxfordshire. Weather at seed harvest was wetter than average in 1968, average in 1969, and drier in 1970. Most seed of good quality came from plant populations of 2–300 000 plants/ha sown in early July, given ample P and K fertiliser in the seedbed and 125–150 kg/ha of N in the spring of the second year in Oxfordshire or 200–250 kg/ha N in Lincolnshire. Harvesting in early September yielded most seed. Methods used to grow multigerm seed proved suitable also for monogerm seed but the percentage germination was sometimes small. In different experiments, monogerm and multigerm crops yielded similar weights of seed and had similar optimum harvest dates.

16.35 WINDER, G. H. (1971) Control of Beet Leaf Miner (*Pegomya betae* (Curt.)) by soil-applied pesticides. *Plant Pathology* **20**, 164–166.

Damage to the leaves of sugar-beet seedlings in eastern England by larvae of *Pegomya betae* (Curt.) was prevented or greatly decreased by drilling aldicarb, 'Dupont 1410', methomyl, 'Mocap' or pirimiphos-methyl at rates in the range 4–60 oz a.i./acre (280–4204 g/ha) in the furrow with the seed.

Soil Survey

BOOKS

17.1 CLAYDEN, B. (1971) Soils of the Exeter district. Harpenden: Rothamsted Experimental Station, x, 254 pp.

17.2 FURNESS, R. R. (1971) Soils in Cheshire I: Sheet SJ 65 (Crewe West). Harpenden: Rothamsted Experimental Station, vii, 99 pp.

17.3 HARROD, T. R. (1971) Soils in Devon I: Sheet ST 10 (Honiton). Harpenden: Rothamsted Experimental Station, viii, 150 pp.

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17.4 HODGSON, J. M. & PALMER, R. C. (1971). Soils in Herefordshire I: Sheet SO 53 (Hereford South). Harpenden: Rothamsted Experimental Station, vi, 81 pp.

17.5 JOHNSON, P. A. (1971) Soils in Derbyshire I: Sheet SK 17 (Tideswell). Harpenden: Rothamsted Experimental Station, viii, 100 pp.

17.6 MATTHEWS, B. (1971) Soils in Yorkshire I: Sheet SE 65 (York East). Harpenden: Rothamsted Experimental Station, vii, 128 pp.

17.7 ROBSON, J. D. & GEORGE, H. (1971) Soils in Nottinghamshire I: Sheet SK 66 (Ollerton). Harpenden: Rothamsted Experimental Station, vi, 82 pp.

17.8 STURDY, R. G. (1971) Soils in Essex I: Sheet TQ 59 (Harold Hill). Harpenden: Rothamsted Experimental Station, vi, 184 pp.

17.9 THOMASSON, A. J. (1971) Soils of the Melton Mowbray district. Harpenden: Rothamsted Experimental Station, vii, 118 pp.

17.10 WHITFIELD, W. A. D. (1971) Soils in Herefordshire II: Sheet SO 52 (Ross-on-Wye West). Harpenden: Rothamsted Experimental Station, vi, 55 pp.

THESIS

17.11 JONES, R. J. A. (1971) Interactions of soil, climate, altitude, aspect and fertiliser treatment on grass production in the upper Don Basin, Aberdeenshire. Ph.D. Thesis, University of Aberdeen.

GENERAL PAPERS

17.12 AVERY, B. W. (1970) Soil variability and soil surveying. *Welsh Soils Discussion Group Report* No. 11, 45–55.

17.13 (BECKETT, P. H. T.) & WEBSTER, R. (1971) Soil variability: a review. *Soils and Fertilisers* **34**, 1–15.

17.14 (BRIDGES, E. M.) & CLAYDEN, B. (1971) Pedology. In: *Swansea and its region.* British Association for the Advancement of Science.

17.15 CORBETT, W. M. (1971) Soil surveying in Norfolk and Suffolk. *Geological Society of Norfolk Bulletin* No. 19, 2–31.

17.16 COURTNEY, F. M. & STAINES, S. J. (1971) Soils in the Westman's Wood Forest Nature Reserve. *Journal of the Devon Trust for Nature Conservation*, 109–114.

17.17 MACKNEY, D. (1970) Podzols in Lowland England. *Welsh Soils Discussion Group Report* No. 11, 64–87.

17.18 RUDEFORTH, C. C. (1971) Early potato soils in Pembrokeshire. In: *Early potatoes in Pembrokeshire.* Ministry of Agriculture, Fisheries and Food, Agricultural Development and Advisory Service (Dyfid Division).

PAPER IN ROTHAMSTED REPORT, PART 2

17.19 AVERY, B. W., BULLOCK, P., CATT, J. A., NEWMAN, A. C. D., RAYNER, J. H. & WEIR, A. H. (1972) The soils of Barnfield. *Rothamsted Experimental Station. Report for 1971*, Part 2, 5–37.

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Research Papers

17.20 Bullock, P. (1971) The soils of the Malham Tarn area. *Field Studies* **3**, 381–408.

The soils are mainly in drift from local Silurian shales, Carboniferous Limestone, Yoredale sandstones, shales and limestones and Millstone Grit, and only thin soils on Millstone Grit pavement and on scree slopes on limestone are probably residual. On Carboniferous Limestone, soil type is closely related to thickness of drift and plant cover. Rendzinas, eutrophic and mesotrophic brown earths occur in thin drift where nutrient cycling by plants maintains the content of bases even with intense leaching. In thick drift, roots cannot reach the limestone and oligotrophic brown earths and peaty gleyed podzols develop beneath a calcifuge vegetation.

There is much peat above 480 m on drift from Yoredale rocks and Millstone Grit and here the main soil types are peat, peaty gley soils and peaty gleyed podzols.

17.21 (Burnham, C. P., Court, M. N.), Jones, R. J. A. & (Tinsley, J.) (1970) Effect of soil parent material, elevation, aspect and fertiliser treatment on upland grass yields. *Journal of the British Grassland Society* **25**, 272–277.

Grass production was measured at 24 places in the Strathdon district of west Aberdeenshire. The mean total yields of DM from two cuts taken from unfertilised plots in 1967 and from three cuts taken in 1968 were 3014 and 3864 kg/ha, respectively. Yields from soils on basic parent material were 30–40% more than yields from soils on more acidic material; and well-managed swards yielded over 40% more than poorly managed ones. Aspect did not affect yields significantly, nor did elevation within the range 260–440 m.

'Nitro-Chalk' applied at the rate of 75 kg N/ha in 1968 increased the DM yield by an average of 35% but the effect of 75 kg P_2O_5/ha, applied as triple superphosphate, was not significant at the 10% level. The benefits from N declined, whereas those from P tended to increase, with elevation. There was no significant NP interaction, but the response from this treatment was better than from N alone on sites with acidic parent material.

In 1968, 46% of the total yield was obtained by the end of June and only 10% after the end of August. Yield declined with elevation in May–June, but increased during July–August.

17.22 (Burrough, P. A., Beckett, P. H. T.) & Jarvis, M. G., (1971) The relation between cost and utility in soil survey (I–III). *Journal of Soil Science* **22**, 359–394.

The whole trial area of 120 km² in Berkshire, in south-central England, was mapped in soil series by free survey at 1 : 25 000 for publication at 1 : 63 360. Three contrasting sample areas of 1·26 km² were resurveyed to the same legend by free survey at 1 : 10 560, and by grid survey at a range of scales between 1 : 20 000 and 1 : 70 000, to both general purpose (soil series) and single-property legends. The direct costs of producing each map were recorded.

The study confirmed how much the free survey depended on external features of soil boundaries to locate them. The density of soil observations needed to map series by free survey at the same map scale in different ground was proportional to the length of mapped boundary/km², or to the number of separately mapped soil occurrences/km². Density was least where soil boundaries had the clearest external expression. Survey effort/km² increased in proportion to the density of observations but was also affected by local differences in the ease of cross-country access, or in the effort necessary (by spade or auger) to identify soil at a point.

For soil series grid surveys there are approximately linear relations between log (cost) and log (map scale) with gradients between 1·3 and 1·7.

A map of soil series by grid survey is more expensive than a map of the same units, based on the same density of observations by the same surveyor, by free survey. But a series map by grid survey by a scientific assistant is cheaper than a series map based on the same density of soil observations by free survey by a scientific officer (diplomate or graduate). The cost of an isoline map of a single soil property depends very much on the cost of determining the property mapped, and to some extent on the number of different isoline maps produced from a single set of samples or observations. Even when costs of chemical analyses are small, an isoline map of one chemical property costs nearly twice as much as a series map by grid survey.

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17.23 CARROLL, D. M. & EVANS, R. (1971) The application of remote sensing methods to soil mapping in England and Wales. *Proceedings of the Seventh International Symposium on Remote Sensing of Environment. Ann Arbor*: University of Michigan.

The use of air photos for soil mapping in England and Wales and current photo-interpretation research in lowland arable and upland areas are described. Experience with colour aerial photography suggests that the additional benefits are small.

17.24 CATT, J. A., CORBETT, W. M., HODGE, C. A. H., MADGETT, P. A., TATLER, W. & WEIR, A. H. (1971) Loess in the soils of north Norfolk. *Journal of Soil Science* **22**, 444–452.

(For summary see No. 3.6.)

17.25 (GAUNT, G. D.), JARVIS, R. A. & MATTHEWS, B. (1971) The late Weichselian sequence in the Vale of York. *Proceedings of the Yorkshire Geological Society* **38**, 281–284.

Three recent radiocarbon dates were used to give an outline chronology and correlation for a sequence of late Weichselian and early Flandrian environments in the Vale of York.

17.26 PRITCHARD, D. T. (1971) Aluminium distribution in soils in relation to surface area and cation exchange capacity. *Geoderma* **5**, 255–259.

Surface area peaks in the B horizons of some acid soils were enhanced by peroxidation and diminished by oxalate extraction, and correlated well with oxalate-extractable aluminium. Cation exchange capacity of the oxalate soluble material depended on pH. The peaks were tentatively attributed to amorphous aluminium oxide.

17.27 (THOREZ, J.), BULLOCK, P., CATT, J. A. & WEIR, A. H. (1971) The petrography and origin of deposits filling solution pipes in the Chalk near South Mimms, Hertfordshire. *Geological Magazine* **108**, 413–423.

(For summary see No. 3.11.)

17.28 WEBSTER, R. (1971) Wilks's Criterion: a measure for comparing the value of general purpose soil classifications. *Journal of Soil Science* **22**, 254–260.

Wilks's Criterion, the ratio of determinants of within-class and total dispersion matrices, measures the relative goodness of a general purpose soil classification, and can determine how many clusters are present in a population, and hence how many classes can be recognised. The first example compares three soil maps of the same area, at different scales. The second shows that only three clusters were recognised in a classification of a set of profiles.

17.29 WHITFIELD, W. A. D. & (FURLEY, P. A.) (1971) The relationship between soil patterns and slope form in the Ettrick association, south-east Scotland. *Institute of British Geographers Special Publication* No. 3, 165–175.

Four slope transects on the Ettrick association were divided into an upper (erosional) and lower (depositional) zone by levelling surveys, field observation and statistical analysis of soil samples. It was confirmed that a junction between the two lay at or about the same point on the slope, although the nature of the junction varied considerably according to the slope profile, pH value is directly related to angle of slope particularly in the upper slope, and that organic matter expressed in terms of percentage organic carbon was inversely related to it throughout the transects. Particle-size distribution was weakly and variably related to slope, indicating little selective removal and deposition of mineral material.

MAPS

17.30 BULLOCK, P., HEATHCOTE, W. R., CRAMPTON, C. B., CROMPTON, A. & MATTHEWS, B. (1971) Soil Map, 1 : 25 000, Sheet SE 74 (Barmby Moor), Southampton: Ordnance Survey.

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17.31 CLAYDEN, B., HARROD, T. R., & MANLEY, D. J. R. (1972) Soil Map, 3rd Edition Sheet 325/339 (Exeter & Newton Abbot), 1 : 63 360, Southampton: Ordnance Survey.

17.32 CORBETT, W. M. & TATLER, W. (1971) Soil Map, 1 : 25 000, Sheet TG 13/14 (Barningham & Sheringham), Southampton: Ordnance Survey.

17.33 FURNESS, R. R. (1971) Soil Map, 1 : 25 000, Sheet SJ 65 (Crewe West), Southampton: Ordnance Survey.

17.34 HARROD, T. R. & STAINES, S. J. (1971) Soil Map, 1 : 25 000, Sheet ST 10 (Honiton), Southampton: Ordnance Survey.

17.35 HARROD, T. R. & STAINES, S. J. (1971) Land Use Capability Map, 1 : 25 000, Sheet ST 10 (Honiton), Southampton: Ordnance Survey.

17.36 HODGSON, J. M. & PALMER, R. C. (1971) Soil Map, 1 : 25 000, Sheet SO 53 (Hereford), Southampton: Ordnance Survey.

17.37 JARVIS, M. G. & JARVIS, R. A. (1971) Soil Map, 3rd Edition Sheet 253 (Abingdon), 1 : 63 360, Southampton: Ordnance Survey.

17.38 JARVIS, R. A. (1971) Soil Map, 1 : 25 000, Sheet SE 60 (Armthorpe), Southampton: Ordnance Survey.

17.39 JARVIS, R. A. (1971) Land Use Capability Map, 1 : 25 000, Sheet SE 60 (Armthorpe), Southampton: Ordnance Survey.

17.40 JOHNSON, P. A. (1971) Soil Map, 1 : 25 000, Sheet SK 17 (Tideswell), Southampton: Ordnance Survey.

17.41 JOHNSON, P. A. & ROBSON, J. D. (1971) Land Use Capability Map, 1 : 25 000, Sheet SK 17 (Tideswell), Southampton: Ordnance Survey.

17.42 MATTHEWS, B. & BULLOCK, P. (1971) Soil Map, 1 : 25 000, Sheet SE 65 (York East), Southampton: Ordnance Survey.

17.43 ROBSON, J. D., GEORGE, H., THOMASSON, A. J. & JOHNSON, P. A. (1971) Soil Map, 1 : 25 000, Sheet SK 66 (Ollerton), Southampton: Ordnance Survey.

17.44 STURDY, R. G. (1971) Soil Map, 1 : 25 000, Sheet TQ 59 (Harold Hill), Southampton: Ordnance Survey.

17.45 STURDY, R. G. (1971) Land Use Capability Map, 1 : 25 000, Sheet TQ 59 (Harold Hill), Southampton: Ordnance Survey.

17.46 STURDY, R. G. (1971) Soil Drainage Map, 1 : 25 000 Sheet TQ 59 (Harold Hill), Southampton: Ordnance Survey.

17.47 THOMASSON, A. J. (1971) Land Use Capability Map, 3rd Edition Sheet 142 (Melton Mowbray), 1 : 63 360, Southampton: Ordnance Survey.

17.48 THOMASSON, A. J., ROBSON, J. D. & JOHNSON, P. A. (1971) Soil Map, 3rd Edition Sheet 142 (Melton Mowbray), 1 : 63 360, Southampton: Ordnance Survey.

17.49 WHITFIELD, W. A. D. (1971) Soil Map, 1 : 25 000, Sheet SO 52 (Ross-on-Wye, West), Southampton: Ordnance Survey.

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