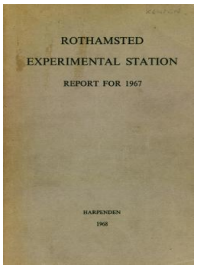
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Physics Department

Book

1.1 Monteith, J. L. (editor) (1967) *Photosynthesis of productive systems.* (English draft by Israel Program for Scientific Translation, Jerusalem, from Russian by A. A. Nichipovorich, Moscow, 1966.)

General Papers

1.2 Penman, H. L. (1968) Evaporation. In: *Manual of British water engineering practice*, 4th edition (Inst. Water Eng., London).

1.3 Penman, H. L. (1965) Defining the plant environment. *Rep. Welsh Pl. Breed. Stn* for 1964, 124–132.

1.4 Penman, H. L. (1967) Weather, 1966. *Trans. Herts. nat. Hist. Soc.* **26**, 209.

Research Papers

1.5 Long, I. F. (1968) Instruments and techniques for measuring the micro-climate of crops. *Proceedings of the British Ecological Society Symposium* (Reading, 1967), pp. 1–32.

A good meteorological station is desirable alongside the experimental site, to measure general local climate. The site should be free from topographical irregularities, and the cropped area should be big enough to provide adequate fetch, and to minimise advective effects. Among quantities to be measured are: temperature (air, soil, plant); humidity (vapour pressure in the air, water content in the soil, dew and leaf-wetness on plants); ventilation; and radiation (total income and components, net and reflected). All need to be measured at several levels (in air, above and within the canopy; in soil, to beyond the expected range of root growth). Continuous recording is desirable, accepting some uncertainty in periods of rain. Standard equipment is rarely adequate. Ignoring radiometry (see 1.10), the paper gives construction details, and examples of performance of instruments designed to measure temperature, humidity and air-flow.

Temperature. Thermo-couples, thermistors and resistance thermometers are compared, with examples of advantageous use. Resistance-thermometer construction is described, to produce units adequate for measuring soil temperatures, leaf temperatures and air temperatures with both dry- and wet-bulbs.

Humidity. The wet- and dry-bulb psychrometer is described, with corrections for less than full ventilation, and a chart for converting temperature readings to vapour pressures. A variation in circuit design will give an approximate estimate of dew-point temperatures, and two such units, at two heights, will give, more accurately, the difference in dew-point between the heights. Three such units (near ground, in canopy, above canopy) can reveal times of onset and duration of persistence of dew, and its source. Very light deposits can be detected by a surface wetness recorder: irrigated and non-irrigated crops give different responses.

Soil-water content can be measured by a neutron-scattering technique that shows where the water is being extracted.

Air-flow. Cup anemometers are used above the crop. A switch system (designed to avoid some foreseeable sources of error) gives one impulse for about 60 metres run of the wind. Logging is automatic (graphical and digital), either on mains or battery operation. Within the crop a hot-bulb anemometer takes up very little space and is more sensitive than rotating cups.

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1.6 PARKINSON, K. J. (1968) Bio-electric potentials of intact green plants. III. Effects of jacketing. *J. exp. Botany*. (In the press.)

When measuring the potential difference between two regions of an oat seedling, if a region of the tissue between the measuring contacts is surrounded by a mineral salt solution, the P.D. may change. This change is shown to be equal to $(E_2 - E_1)/(1 + R_2/R_1)$, where E_1 is the E.M.F. generated by the shunted tissue and R_1 its resistance, and E_2 is the net E.M.F. generated at the shunting solution and the tissue interfaces and R_2 the shunt resistance, expected to be proportional to the specific resistance of the shunting solution. However, in these experiments R_2/R_1 was close to unity due to a large tissue to shunting solution resistance and there was no relationship between the P.D. change and the resistance of the shunt. Where the shunt was applied between two dissimilar regions of the plant (coleoptile and primary leaf), E_2 changed with concentration of the shunting solution, and hence the measured potential difference changed by various amounts. When the shunt was applied to a primary leaf alone E_2 was independent of solution concentration and the change in P.D. was constant.

1.7 PENMAN, H. L. (1968) The inefficiency of world farming. In: *Centennial Symposium, Faculty of Agricultural Sciences, American University of Beirut, Lebanon.*

Agriculture is a method of conserving solar energy for future use: a theoretical upper limit for the efficiency of fixation is near 10%. Where agriculture is treated as an industry, good farming achieves an efficiency near 1%, some experiments do better and for short periods within a growing season efficiencies of 3 or 4% have been attained. It needs fundamental research to determine what are the limitations on improvement of good farming. Over much of the world—using cereals as a test-crop group—efficiency is not much above 0·1%, in a few countries because of lack of rain but in most for other reasons. In the first group irrigation will help, but elsewhere there are probably other limiting factors that need diagnosis and attention first: irrigation can never be a substitute for skilful management of healthy crops.

1.8 PENMAN, H. L. (1968) Available and accessible water. *Proc. 9th int. Congr. Soil Sci.* (Adelaide 1968.)

Measurements on a loam soil gave a diffusity ranging from 20 (wilting point) to 200 (near field capacity) $cm^2\ day^{-1}$. Starting with these data, transfer rates are calculated for a complete crop cover on such a soil, with the root system arranged in parallel sheets (40 cm deep) at two spacings (2 and 20 cm); with and without a deep subsoil; for two imposed rates of potential evaporation (0·2 and 0·6 cm day^{-1}); and with all further resistance either wholly in the atmosphere or all in the plant. Drastic mathematical and physical assumptions are necessary.

Results are as curves of accumulated actual evaporation, ΣE_A, against accumulated potential evaporation, ΣE_T. The curves vary as greatly as published field experience. The main results are: (i) the larger E_T, the smaller the value of ΣE_T at which ΣE_A becomes less than ΣE_T; (ii) at close spacing (dense root system) it is immaterial whether the external resistance is in the plant or in the atmosphere, but at wide spacing plant resistance (if any) can cause an early check to transpiration; (iii) when there is no subsoil the Veihmeyer concept is very nearly exact, particularly at the lower rate of potential evaporation.

1.9 ROSE, D. A. (1968) Water movement in dry soils. I. Physical factors affecting sorption of water by dry soil. *J. Soil Sci.* **19**. (In the press.)

Semi-infinite columns of dry soil closed at one end had the other exposed to a turbulent atmosphere at constant relative humidity (0·98) and a range of constant

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temperatures. After varied times the water content of the columns was measured gravimetrically, in 1-cm layers, from which the total quantity taken up, Q, and the distribution of water content θ with time t and distance x were found. Assuming that the Boltzmann transform, $\lambda = xt^{-1/2}$, can be applied to the standard diffusion equation, two soil parameters are derived. A test of the assumption is that θ should be uniquely dependent on λ, and then the *diffusivity* is calculable from

$$D(\theta) = -\tfrac{1}{2}\frac{d\lambda}{d\theta}\int_{\theta_i}^{\theta}\lambda d\theta$$

where θ_i is the initial uniform water content. The second parameter—the *sorptivity*, $S = Qt^{-1/2}$—is not independent of θ_i or the value maintained at $x = 0$.

Results show that in a clay soil, between pF 5·8 and 4·2 water moves predominantly as vapour: in a non-swelling silicate mineral (sepiolite) there is significant liquid movement between pF 5·1 and 4·2. Long-continued use of organic manure has little effect on either D or S; aggregate size has some effect, in opposite senses for a sand and a clay; a mulch or a still atmosphere affects S but not D; evaporation suppressants decrease S; ignition decreases S and greatly alters D; and degradation of structure causes small changes in D.

1.10 SZEICZ, G. (1968) Measurement of radiant energy. *Proceedings of the British Ecological Society Symposium* (Reading, 1967), 109–130.

Total solar radiation falling on a horizontal surface can be divided into two components: direct radiation from the sun, and diffuse radiation from the sky. A different but, for ecologists, more important division is by spectral regions: the solar spectrum in the 0·3–3·0-μ band can be split into visible or photosynthetically active radiation between 0·4 and 0·7 μ and near infra-red radiation between 0·7 and 3·0 μ.

Atmospheric water vapour, carbon dioxide and the surface of the earth also exchange radiation with an intensity proportional to the fourth power of their absolute temperatures. This radiation is commonly referred to as long-wave exchange; the spectrum extends from about 3 to 80–100 μ.

Most of the net radiant energy—the balance between all the incoming and outgoing components—when absorbed by plants and animals is transformed into heat. To dispose of this large amount of energy—about half a kilowatt per square metre in bright sunshine—plants transpire, animals sweat and both expose themselves to the cooling wind. Between 0·4 and 0·7 μ some of the absorbed radiation is used in photosynthesis and a small fraction of it is stored in the end products. The human eye is also sensitive to this region, but with a different and well-defined spectral response.

Incoming and reflected solar radiation are measured by thermopiles whose surfaces are protected from wind and weather by glass domes. Visible radiation is measured by combining the thermopiles with cut-off glass filters. Net radiation is measured with blackened flux-plates, which are either protected by polythene domes or ventilated by a fast jet of air that swamps the effects of the wind. Inside crops, where radiation is uneven, long tubular solarimeters and net-radiometers can be used to give good spatial averages.

Solarimeters are calibrated against sub-standards in Meteorological Office networks, and net radiometers in turn can be calibrated against solarimeters by "shading". For photocells calibrated against solarimeters in daylight, caution is necessary when using them in artificial light. Because of their uniform spectral response, thermopiles read in absolute energy units but photocells in units of

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luminous energy. The two are comparable only when the spectral composition does not change appreciably with intensity.

To obtain consistency and good quality in measurements, it is often worthwhile to seek advice from meteorologists or physicists on the availability of measurements in the national network, and on facilities for calibration.

1.11 THOM, A. S. (1968) The exchange of momentum mass and heat between an artificial leaf, and the air flow in a wind tunnel. *Quart. Jl. R. met. Soc.* **94**, 44–55.

Investigation of a proposed relationship between the skin friction part of the drag on a natural surface and a simultaneous transfer of mass or (sensible) heat led to measurements of the dimensionless transfer coefficients C_d, C_v and C_h for the exchange of (stream-wise) momentum, mass and heat between a single artificial leaf and the airflow in a wind-tunnel. It was shown that $C_{v,h} = C_0(D/\nu, \kappa/\nu)^{2/3}$ where D, κ and ν are the molecular diffusivities in air of gas or vapour, heat and momentum, and where C_0 is a generalised mass or heat-transfer coefficient almost independent of ϕ, the angle of incidence between the leaf and the airflow. C_d, however, made up of a bluff-body or pressure part C_b, in addition to a molecular skin-friction part C_f, depended strongly on ϕ. C_0 was close to the theoretical skin-friction drag coefficient at $\phi = 0$ of a thin flat plate with dimensions similar to the leaf. As a general relation between the corresponding coefficients of a natural rough surface $C_F = \beta C_0$, where β lies between 0·1 and unity, depending on the form and inclination (ϕ) of the roughness elements, and on wind speed.

C_0 was shown experimentally to be proportional to (wind speed)$^{-1/2}$ in a regime of fully forced convection. When the evaporation from one side of the leaf was stopped the transfer coefficient for the removal of vapour from the other side increased by about 30%. An accurate form of the psychrometric constant of the leaf includes the factor $(\kappa/D)^{2/3}$, which has the value 0·90 for water vapour.

Chemistry Department

THESIS

2.1 BOLTON, J. (1967) The distribution and availability to plants of sodium and other cations in soils. Ph.D. Thesis, University of London.

GENERAL PAPERS

2.2 BENZIAN, B. (1967) Nutrition experiments in forest nurseries. *Phosphorus in Agriculture*, No. 46, 29–35; French edition: *Phosphore et Agriculture*, No. 46, 35–43 (*Bull. Docum. Ass. int. Fabr. Superphos.* No. 46).

2.3 BENZIAN, B., BOLTON, J., COULTER, J. K. & MATTINGLY, G. E. G. (1967) Nutrition experiments in forest nurseries. *Rep. Forest Res., Lond.*, 1966, 99–102.

2.4 BENZIAN, B., BOLTON, J., & MATTINGLY, G. E. G. (1967) Nutrition experiments in forest nurseries. *Rep. Forest Res., Lond.*, 1967, 133–134.

2.5 BENZIAN, B. & FREEMAN, S. C. R. (1967) Effect of "late-season" N and K topdressings applied to conifer seedlings and transplants, on nutrient concentrations in the whole plant and on growth after transplanting. *Rep. Forest Res., Lond.*, 1967, 135–140.

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2.6 COOKE, G. W. (1967) Advice on using fertilisers 1861–1967. *Jl. R. agric. Soc.* **128**, 107–124.

2.7 COOKE, G. W. (1967) The effect of farming systems, crop rotations and other factors on the profitability of fertilisers used on arable crops and grassland. Symposium on the economic aspects of the use of fertilisers. Geneva. Published by FAO, Geneva, ST/ECE/AGRI/26, Vol 1, pp. 92–147.

2.8 COOKE, G. W. (1967) The value, and valuation of fertiliser residues. *Jl. R. agric. Soc.* **128**, 7–25.

2.9 COOKE, G. W. (1968) How serious is soil compaction? *Arable Fmr* **2**, no. 3, 16–19.

2.10 COOKE, G. W. (1968) Soil fertility problems in cereal growing. *Ceres* no. 2, pp. 3–6.

2.11 SALT, P. D. (1967) Determination of potassium and rubidium in the presence of each other. Method Sheet No. 900/12, June 1967. Unicam Instruments Ltd., Cambridge.

2.12 SALT, P. D. (1967) Soil and plant analysis by flame emission spectrophotometry. *Spectrovision* no. 18, pp. 9–12.

2.13 WIDDOWSON, F. V. (1968) Why starve grass? *Dairy Farmer* February, 34–36, 55.

RESEARCH PAPERS

2.14 DEIST, J. & TALIBUDEEN, O. (1967) Ion exchange in soils from the ion pairs K–Ca, K–Rb and K–Na. *J. Soil Sci.* **18**, 125–137.

Isotopic exchange of ^{42}K, ^{24}Na, ^{86}Rb and ^{45}Ca was used to measure the equilibria between some arable soils and mixed chloride solutions of the ion pairs K–Ca, K–Rb and K–Na; the results were interpreted by a thermodynamic treatment of the exchange isotherm. The cation-exchange capacities of the soils were not constant for the three ion pairs and decreased appreciably with K-saturation in the K–Ca systems because Ca ions were trapped inside the interlayer spaces. That soils preferred K to Na in the K–Na systems, and Rb to K in the K–Rb systems, is explained in terms of the standard free-energy changes of the exchange reactions.

The activity coefficients of the adsorbed ions, f, changed with K-saturation differently for the three ion pairs: f_{Na} and f_{Ca} decreased continuously with increasing K-saturation, whereas f_{Rb} remained almost constant. However, with increasing K-saturation f_K increased in the K–Na systems, remained unchanged in the K–Rb systems and first increased and then decreased in the K–Ca systems. These changes are interpreted in terms of the effect of the various ions on the interlayer space of 2 : 1 type clay minerals and the possible distribution of adsorbed ions between the Gouy and Stern layers.

2.15 DEIST, J. & TALIBUDEEN, O. (1967) Rubidium 86 as a tracer for exchangeable potassium in soils. *Soil Sci.* **104**, 119–122.

A method using Rb86-labelled RbCl solution was tested on four contrasting soils to determine from the kinetics of Rb exchange, the amount of fixed Rb^+ adsorbed on cation-exchange sites in soils not accessible to K^+ ions. The values obtained are closely related to the clay contents of the soils. Rb : K exchange corrected for such fixed Rb gives values for exchangeable K very similar to K^+

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exchangeable to N ammonium acetate. It is suggested that Rb86 could be used in experiments lasting 4–5 months with plants in the glasshouse to determine the K available to plants, provided the results were corrected for such fixed Rb^+, determined by the simple exchange kinetics experiment described, and the results corrected accordingly.

2.16 DEIST, J. & TALIBUDEEN, O. (1967) Thermodynamics of K–Ca ion exchange in soils. *J. Soil Sci.* **18**, 138–148.

Cation-exchange characteristics of the K : Ca saturated forms of five soils were measured at 25° and 50° C. Isotopic exchange of ^{42}K and ^{45}Ca was too fast to be measured except of ^{42}K in the K : Ca Harwell soil at 25° C. The slower isotopic exchange of K in this soil was attributed to the presence of a zeolite, clinoptilolite. The intra-particle diffusion coefficient, D_i, of K in this soil increased with K-saturation to a maximum at about 40% K, probably because of the "blocking" action of the larger hydrated Ca ions at small K-saturations in clinoptilolite.

The CEC, measured by isotopic exchange along the K : Ca adsorption isotherm, decreased with increasing temperature, probably because some interlayer spaces collapsed.

The standard free energy, enthalpy and entropy changes were negative for the reaction Ca-soil + $2K^+ \rightleftharpoons$ 2K-soil + Ca^{++}. These results seem to show that K is more strongly bound than Ca by the soil and that the Ca-preference shown by the isotherm at small external electrolyte concentration is caused by entropy changes in solution.

Calculated activity coefficients of the exchangeable ions changed with K-saturation similarly at both temperatures, but values at 50° C were smaller than at 25° C.

2.17 GASSER, J. K. R., GREENLAND, D. J. & RAWSON, R. A. G. (1967) Measurement of losses from fertiliser nitrogen during incubation in acid sandy soils and during subsequent growth of ryegrass, using ^{15}N-labelled fertilisers. *J. Soil Sci.* **18**, 289–300.

Ammonium sulphate and calcium nitrate both containing excess ^{15}N were applied to four acid sandy soils; two were from old arable fields and two from grassland, selected so that one of each pair was about pH 5 and the other about pH 6 (in water). The soils were incubated for 6 weeks at 21° C in large glazed earthenware pots, one set with the nitrification inhibitor 2-chloro-6-(trichloromethyl)-pyridine added and another without. Ammonium and nitrate N were determined at intervals, and the total-N at the start and after 6 weeks. The atom per cent ^{15}N in the mineral-N extracted from soils treated with ammonium sulphate was determined after 0, 3 and 6 weeks, and in the total-N of all the soils given N-fertiliser at 0 and 6 weeks.

Much added N was immobilised at first, but some was re-mineralised during the second half of the incubation. Mineral-N extracted from soils treated with ammonium sulphate contained less ^{15}N than the fertiliser added, showing that part of the apparent re-mineralisation during the second half was from unlabelled soil organic matter.

After incubating for 6 weeks less than 5% of the N added as nitrate was lost, but about 5% of the labelled-N added as ammonium sulphate was lost from the two grassland soils. Adding the inhibitor prevented this loss.

After incubating, the soil remaining in each jar was halved to provide duplicate pots and sown with ryegrass. A similar series of pots with the same treatment

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(but with unlabelled fertiliser) was also prepared from the soils that had been stored slightly moist and at 21° C; these were sown with ryegrass. All pots were harvested after 42 days and again after 70 days.

More than 93% of the labelled-N was recovered in plants and soil, except from the two grassland soils to which calcium nitrate was added. It is concluded that, although a little nitrogen may be lost during nitrification in some of these soils, more nitrogen may be lost during the growth of grass, when nitrate is relatively abundant.

The nitrification inhibitor decreased yields of grass at the first cutting on grassland soils treated with ammonium, but increased them on soil treated with nitrate, suggesting that changing the proportions of nitrate to ammonium by adding the inhibitor alters the growth rate and yield of grass.

2.18 GASSER, J. K. R. & IORDANOU, I. G. (1967) Effects of ammonium sulphate and calcium nitrate on the growth, yield and nitrogen uptake of barley, wheat and oats. *J. agric. Sci., Camb.* **68**, 307–316.

Barley, wheat and oats were grown in the field and in pots without fertiliser-N, and with ammonium sulphate or calcium nitrate. In the field fertilisers supplied 50 and 100 lb N/acre, in the glasshouse 100 and 200 lb N/acre (calculated from the surface area of the pots). Plant samples were removed at various stages, dry weights measured, percentage N determined and N uptake calculated. Samples taken after the ears had emerged were divided into ear and straw. The coleoptiles emerging, and ears in the later samples, were counted. Soil samples were taken after removing the plants grown in the glasshouse, and analysed for ammonium and nitrate.

In the glasshouse dry matter produced and N uptake depended on the amount of N available, and increased with increasing fertiliser-N applied. The forms did not affect yield of dry matter or N uptake. Soil analyses showed that all ammonium fertiliser-N was nitrified 46 days after sowing.

In the field dry matter was increased by applying fertiliser-N, although the increase from the second increment was much less than from the first. N uptake depended on the amount applied, and increased with each increment of fertiliser-N. On average of all crops with fertiliser-N, more dry matter was produced by nitrate-N than by ammonium-N in the later stages of growth, and more N was taken up from nitrate than from ammonium.

From flowering to maturity, the N content of straw decreased for all three crops and the N content of the grain increased. The weight of barley straw as dry matter similarly decreased, but wheat and oat straw weighed most at the mealy ripe stage.

The recovery of fertiliser-N by barley and wheat fluctuated about values of 58 and 69% from 56 days to harvest, whereas the recovery by oats was 98% after 80 days (flowering), decreasing to 59% at harvest.

Although applying fertiliser-N usually increased the number of ears per square foot, dry matter per ear and N uptake per ear for crops both in the field and glasshouse, the effects differed between crops. Similar percentages of applied N were recovered from the smaller and larger amounts by crops grown in the greenhouse, whereas in the field the recovery from the larger dressing was less than from the smaller.

2.19 GASSER, J. K. R. & PENNY, A. (1967) The value of urea nitrate and urea phosphate as nitrogen fertilisers for grass and barley. *J. agric. Sci., Camb.* **69**, 139–146.

Urea nitrate, urea phosphate and a mixture of urea phosphate and urea were tested as nitrogen fertilisers to find whether the presence of the anion decreases

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the damage urea does to germinating seeds and seedlings and increases the efficiency of urea by preventing loss of ammonia.

Urea nitrate was compared with ammonium sulphate for grass grown in pots in the glasshouse and with ammonium nitrate for permanent grassland in the field. In the glasshouse a large dressing of urea nitrate damaged the early growth of grass in sandy-loam soil. On average of sandy-loam and clay-loam soils with a small dressing of fertilisers, grass recovered similar amounts of N from urea nitrate and ammonium sulphate; with the large dressing it recovered less from urea nitrate.

In the field 100 and 200 lb N/acre were applied to permanent grass, which was cut twice. The herbage was "scorched" by the urea nitrate because its solution is very acid. Urea nitrate at 200 lb N/acre produced less dry matter, containing less nitrogen, than did ammonium nitrate.

Urea nitrate, urea phosphate and urea phosphate–urea mixture were compared with ammonium nitrate for barley and grass grown in clay-loam and sandy-loam soils. Tests were made of 33, 67 and 100 lb N/acre for barley and 100, 200 and 300 lb N/acre for ryegrass; the fertilisers were applied immediately before sowing. On the light Woburn soil early growth of barley was least good with urea nitrate, which also damaged the early growth of grass.

Urea nitrate was as good a nitrogen fertiliser as ammonium nitrate; urea phosphate and urea phosphate–urea mixture were better.

Urea nitrate damaged early growth because the urea hydrolysed to give free ammonia. The nitric acid probably does not decrease the damage because it is mobile and diffuses rapidly through a large soil volume.

Urea phosphate does not damage plant growth because the phosphoric acid is relatively immobile and makes the soil around the granules acid; this causes the urea to diffuse into a larger soil volume before being hydrolysed, and also provides the locally acid soil needed to absorb free ammonia released from the urea.

Both fertilisers have good physical forms. Urea nitrate is a dry crystalline powder, and urea phosphate crystallises easily. Urea phosphate has constant composition and seems a potentially valuable intermediate for producing NP or NPK mixed fertilisers. With present agricultural practice, urea nitrate has much less potential use as a fertiliser.

2.20 HOYT, P. B. (1967) Chlorophyll-type compounds in soil. III. Their significance in arable soils. *Pl. Soil* **26**, 5–13.

The quantities of chlorophyll-type compounds in a group of 24 arable soils were significantly correlated with nitrogen uptake ($r = 0{\cdot}79$) and yield ($r = 0{\cdot}84$) of ryegrass grown in pots in the glasshouse. Partial correlation coefficients showed the amounts of mineral N released on incubating the re-wetted air-dry soils were related both to chlorophyll units (measure of chlorophyll-type compounds) and organic C. The chlorophyll units (CU) apparently represented some fraction of organic matter that liberated inorganic nitrogen, because chlorophyll-type compounds in the soil were not enough (only 0·5–3·0 lb/acre) to supply this nitrogen. The compounds were probably a residue that resisted decomposition. The CU in soil ploughed from ley decreased very slowly during 3 years of arable cropping.

2.21 KUBOTA, T. & WILLIAMS, R. J. B. (1967) The effects of changes in soil compaction and porosity on germination, establishment and yield of barley and globe beet. *J. agric. Sci., Camb.* **68**, 227–233.

Two degrees of compaction, "heavy" with a flat-tyred vehicle wheel and "light" with a ring roller, were given to the seed-beds after sowing barley and globe beet

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on three contrasted soils. Changes in pore space of the soils and the responses of the crop to the changed physical properties were measured. The sites used were: Barnfield at Rothamsted, a heavy clay loam long under arable cultivation and containing little organic matter; Pastures Field at Rothamsted, a field of silty clay loam ploughed after an 8-year ley; Stackyard field at Woburn, a light sandy loam long in arable cultivation and containing little organic matter.

The contributions of the large-sized pores to total pore space in 1-in.-diameter clods was lessened by compaction, whereas the small-sized pores (<0·04 mm diameter) in the 1–2-mm aggregates were not affected. The effects of compaction became less with depth and were negligible 8–10 in. deep. The heavy soils compacted more than the light soil. The heavy soil where the ley had grown showed very little effect from compaction at 3–6 in. depth.

Germination of barley was related to the pore space contributed by the large-sized pores in the top 3 in. of soil. The apparent density critical for germination was greater on the light than on the heavy soils.

On the light soil, compaction increased the tendency to form a hard surface pan, which severely restricted root penetration; on the heavy soils, surface cracking diminished adverse conditions for crop growth caused by compaction.

"Light" compression with a ring roller did not depress yields of either globe beet or barley on the heavy soils, but did on the light soil. Heavy compaction with the vehicle wheel decreased crop yields greatly on the light soil, less on the heavy arable soil and least on the heavy soil following a long ley.

The concentration of N, P, K and Mn in the crops at harvest were not consistently related to the compaction treatments. Compaction lessened the ratio of phosphorus/nitrogen taken up by the crops on the light soil, but effects on uptake from the heavy soils were much smaller.

2.22 WIDDOWSON, F. V., PENNY, A. & WILLIAMS, R. J. B. (1967) Results of an experiment at Woburn testing farmyard manure and N, P and K fertilisers on five arable crops and on a long ley. II. N, P and K removed by the crops. *J. agric. Sci., Camb.* **68**, 293–300.

From 1960 to 1964 an experiment at Woburn measured yields and the amounts of N, P and K removed by five arable crops (barley, grass–clover ley, potatoes, oats and sugar beet) and by a long ley; each was manured with all combinations of N, P and K fertilisers and with farmyard manure (D) and with both fertilisers and farmyard manure (DN_1PK and DN_2PK).

The amounts of N, P and K obtained by each crops from the soil were measured. Sugar beet (tops and roots) and potatoes (tubers only) obtained most N (82 and 67 lb respectively) and oats and barley (grain and straw) least (24 and 21 lb/acre respectively). The rotation ley (grass and red clover) fixed more than 250 lb N (in four cuts, one of which was in the seeding year) when given PK, and the long ley (grasses and white clover) fixed 120 lb N/acre annually. The leys and the sugar beet obtained most P (21 and 18 lb P/acre) and barley least (7 lb/acre). The rotation ley and the sugar beet removed most K (138 and 132 lb/acre respectively) and barley the least (20 lb/acre). The amounts of N, P and K removed by each crop differed greatly in different years, and did so most with K (range 1 : 4) and least with N (range 1 : 2).

The amounts of N, P and K apparently recovered from the fertilisers were also measured. Sugar beet (roots and tops) recovered most N (58 and 76% of the single and double dressing respectively), and potatoes (tubers only) the least (38 and 32%). The rotation ley recovered most P (12%) and oats the least (2%). They recovered much more K; the long ley and the rotation ley recovered most (61 and 54% respectively) and oats and barley the least (11 and 9%). The mean

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recovery by potatoes and sugar beet was small, because initially they did not respond to K.

The mean amounts of N, P and K added in 20 tons/acre of FYM were 292, 124 and 315 lb/acre respectively. Of this, potatoes and sugar beet recovered mean amounts of 43 lb N, 8 lb P and 80 lb K/acre and slightly more when fertilisers were also given. Sugar beet and potatoes took up less N from FYM than from ammonium nitrate, and the percentage recovery was also smaller, but they recovered more P from FYM than from superphosphate, and the percentage recovery was three times larger. They also took up more K from FYM than from potassium bicarbonate, but the percentage recoveries from FYM and from potassium bicarbonate were similar. The long ley recovered proportionally less N and K, but more P, from FYM than from fertilisers.

The amounts of N, P and K removed by the five arable crops (lb/acre) ranged from 400 to 800 of N, 50 to 100 of P and 250 to 900 of K. The largest losses from the soil (after subtracting the N added by the clover ley) were about 200 lb of N, 65 of P and 400 of K, and the largest gains to the soil (from manuring) were 500 lb of N, 270 of P and 500 of K.

2.23 WIDDOWSON, F. V., PENNY, A. & WILLIAMS, R. J. B. (1967) Experiments measuring effects of ammonium and nitrate fertilisers, with and without sodium and potassium, on spring barley. *J. agric. Sci., Camb.* **69**, 197–207.

Thirteen experiments, made on soil overlying chalk, compared yields of spring barley at ear emergence, and of ripe grain, from ammonium sulphate and from calcium nitrate, from sodium nitrate or sodium chloride or both, and from potassium nitrate or potassium chloride. The amounts of N, K, Na and Mg in the green barley, and of N in the grain, were measured.

N greatly increased grain yields in all but one experiment, where the barley followed sugar beet. Calcium nitrate gave larger grain yields than ammonium sulphate in three-quarters of the comparisons, but gave much smaller yields than ammonium sulphate on one light soil in 1964 when much rain fell after the fertilisers had been applied. Grain yields from calcium, potassium and sodium nitrates were nearly the same.

Na slightly increased grain yields in three and K in two experiments; combine-drilled P or PK fertilisers increased them in every experiment.

Dry yields of green barley (at ear emergence) and of grain were similar, but each year the green barley contained more N than the grain.

In the green barley % K and % Na were increased greatly, and % Mg slightly, by increased N. % K was slightly increased by K and by Na; % Na was doubled by Na and decreased by K; % Mg was decreased by Na and K.

The mean ranges in uptake (lb/acre) by the green barley were 61–120 of K, 2·1–10·8 of Na and 2·7–5·1 of Mg.

2.24 WIDDOWSON, F. V., PENNY, A. & WILLIAMS, R. J. B. (1967) Experiments comparing the effects on yields of potatoes of three methods of applying three amounts of NPK fertiliser and the residual effects on following winter wheat. *J. agric. Sci., Camb.* **69**, 247–253.

Seven experiments on heavy soils from 1962–65 measured yields of main-crop potatoes with 0, 5, 10 or 15 cwt/acre of 13–13–20 fertiliser; (1) broadcast and worked into the soil by seed-bed preparations; (2) broadcast on the final seed-bed; (3) placed in bands 3 in. from the seed centre. Wheat followed the potatoes and was given 0, 5 or 10 cwt/acre of the equivalent of 13–13–20 fertiliser, in all combinations with the fertiliser treatments for the potatoes.

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Fertiliser greatly increased potato yields and 15 cwt/acre of 13–13–20 was justified, provided it was broadcast. Both methods of broadcasting gave similar yields with 5 or 10 cwt/acre, but with 15 cwt/acre working the fertiliser into the seed-bed usually gave more. Placing in bands beside the seed was the best method in four experiments with 5 cwt, in two with 10 cwt, but never with 15 cwt/acre of fertiliser.

Yields of green wheat, and of grain and of straw, were increased by residues of fertiliser applied for the potatoes, but were increased much more by freshly applied fertiliser. The increases in grain from the residues equalled those produced by one-quarter as much freshly applied fertiliser. The residues had smallest effects when the winter was wettest, and effects were the same however the fertiliser had been applied.

Green wheat (at ear emergence) contained slightly more N, one-fifth less P, but two and a half times more K than the ripe grain and straw together.

Pedology Department

Research Papers

3.1 Bloomfield, C. (1967) The effect of some phosphate fertilisers on the oxidation of elemental sulphur in soil. *Soil Sci.* **103**, 219–233.

The oxidation of elemental sulphur contained in granulated diammonium phosphate and triple superphosphate mixtures and in wax-coated diammonium phosphate pellets was compared with the oxidation of sulphur alone. The fertilisers were incubated for 20 weeks in a silty clay loam (pH 4·4) with and without calcium carbonate.

Diammonium and triple superphosphate promoted the oxidation of sulphur in both acid and calcareous soil.

About the same amount of sulphur was oxidised in the acid soil with wax-coated pelleted diammonium phosphate as with sulphur alone, but in the limed soil considerably more was oxidised with sulphur alone. In the acid soil most sulphur was oxidised with the granulated superphosphate, and in the limed soil most with the granulated diammonium phosphate.

After incubating for 20 weeks very much less phosphate could be extracted from the wax-coated pelleted form than from the granulated diammonium phosphate.

3.2 (Hodgson, J. M.), Catt, J. A. & Weir, A. H. (1967) The origin and development of Clay-with-flints and associated soil horizons on the South Downs. *J. Soil Sci.* **18**, 85–102.

Clay-with-flints rests on remnants of the exhumed sub-Eocene surface, which is shown to be an important geomorphological feature of the West Sussex Downs. Mineralogical and other soil-profile studies indicate that the deposit has developed by the action of cryoturbation and soil-forming processes on a thin cover of Reading Beds clay left on the sub-Eocene surface during the southward recession of a small Eocene escarpment. Two horizons corresponding to Clay-with-flints *sensu stricto* of Loveday (1962) are recognised. The basal horizon is composed partly of insoluble Chalk residue, but mainly of clay moved down from overlying horizons into the spaces left on dissolution of the Chalk at the junction of the Chalk with the base of the Clay-with-flints. The upper horizon is composed of material from weathered remnants of Reading Beds clay, thoroughly mixed by cryoturbation with flints, other insoluble Chalk residue and clay from

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former basal horizons. The surface horizons of the soils often include additions of loess.

3.3 JENKINSON, D. S. (1968) A chemical test for potentially available nitrogen in soil. *J. Sci. Fd Agric.* **19**, 160–168.

Previous work on the distribution of radioactivity in the organic matter of soils incubated with ^{14}C-labelled ryegrass suggested that the amount of organic matter extracted by barium hydroxide might serve as an index of potentially available nitrogen in soil. This suggestion was tested on a set of soils for which the amounts of nitrogen mineralised during incubation, and the amounts of nitrogen taken up by ryegrass grown in the soils, were known. The amounts of organic carbon and non-nitrate nitrogen extracted by barium hydroxide correlated fairly closely with the amounts of nitrogen released by the soils: polysaccharide (measured as the glucose equivalent) extracted by barium hydroxide was more closely correlated with release of nitrogen. The amount of "glucose" extracted was significantly correlated with the yield of unfertilised barley in 36 field experiments ($r = 0{\cdot}83^{**}$); the correlation with response of barley to nitrogen was smaller ($r = -0{\cdot}54^{**}$).

The amount of "glucose" extracted from soil by barium hydroxide increased during air-drying, but once air-dry, no further change occurred, even on prolonged storage.

Barium hydroxide extractable "glucose" is proposed as an index of potentially available nitrogen in soil; it gave results as good or better than those from four other chemical tests for assessing the availability of nitrogen to plants. The correlation coefficients between uptake of nitrogen by ryegrass grown in pots (14 soils) and soil measurements were $0{\cdot}70^{**}$, $0{\cdot}65^{*}$, $0{\cdot}70^{**}$, $0{\cdot}67^{**}$ and 0·28, respectively, for barium-hydroxide-extractable "glucose", boiling-water-extractable nitrogen, sodium-bicarbonate-extractable nitrogen, ammonia released by hot aqueous calcium hydroxide and ammonia released by alkaline permanganate. None of the chemical tests correlated as closely with uptake of nitrogen by grass as did the nitrogen mineralised on incubating the rewetted air-dried soil.

3.4 JENKINSON, D. S. (1968) Studies on the decomposition of plant material in soil. III. The distribution of labelled and unlabelled carbon in soil incubated with ^{14}C labelled ryegrass. *J. Soil Sci.* **19**, 25–39.

The organic matter in soils containing decomposing ^{14}C-labelled ryegrass was fractionated chemically. Earlier work on these soils showed that they contained a small fraction, heavily labelled relative to the rest of the soil organic matter, that was mineralised when the partially sterilised soils were incubated. Reagents effective in extracting heavily labelled-C included cold 0·1*N*-HCl, boiling saturated $CaSO_4$ solution and 0·1*N*-$Ba(OH)_2$, but neither these nor any other reagent tested could extract material as heavily labelled as that mineralised when partially sterilised soil was incubated. Reagents that extract heavily labelled-C are poor extractants for humified material and are not strongly hydrolytic: the more vigorous the hydrolysis, the smaller the proportion of labelled-C in the hydrolysate. The amounts of labelled-C dissolved by $Ba(OH)_2$ from soils sampled after different periods in the field were directly proportional to the amounts of labelled-C mineralised by those soils when partially sterilised (by exposure to $CHCl_3$ vapour), inoculated and incubated.

Balance sheets are presented for the distribution of labelled and unlabelled-C in fractions separated by hydrolysis with 6*N*-HCl, by NaOH extraction, by neutral pyrophosphate extraction and by oxidation with H_2O_2. The fraction

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remaining after hydrolysis with 6*N*-HCl was the most lightly labelled and had the widest C/N ratio. The percentage of labelled-C in the material dissolved by alkali or by pyrophosphate was little more than in the material not dissolved, despite the presence in the soil of fractions differing at least twenty-fold in intensity of labelling.

3.5 KING, H. G. C. & HEATH, G. W. (1967) Studies in leaf litter breakdown. III. The chemical analysis of small samples of leaf material and the relationship between the disappearance and composition of leaves. *Pedobiologia* **7**, 192–197.

A scheme of analysis for determining factors that possibly influence palatability to soil fauna, for example, texture, nutritional value and astringency, is described. The scheme is suitable for 0·5–1·0 g leaf material.

Analyses of autumn-fallen oak leaves, not exposed to soil fauna and graded subjectively into hard and soft categories, showed significant differences in polyphenol, total nitrogen, lignin, cellulose and sugar contents.

3.6 KING, H. G. C., PRUDEN, G. & JANES, N. F. (1967) The synthesis of the active component of commercial Titan yellow for use in the determination of magnesium. *Analyst, Lond.* **92**, 695.

The sodium sulphonate groups of the magnesium-reactive component of commercial Titan yellow are shown to be in the 7-position on each of the benzthiazole rings. Titan yellow synthesised from 2-(*p*-aminophenyl)-6-methyl benzthiazole 7-sulphonic acid is reliable and sensitive in the determination of magnesium.

3.7 KING, H. G. C. & BLOOMFIELD, C. (1968) The effects of drying and aging tree leaves on the ability of their aqueous extracts to dissolve ferric oxide. *J. Soil Sci.* **19**, 67–76.

Extracts of freshly collected picked and autumn-fallen oak, beech and larch leaves were compared with those of leaves from the same collection that were either freeze-dried or dried at 105° C. The iron-dissolving properties of the fallen leaves were not significantly affected by either method of drying, but drying at 105° C greatly increased the activities of picked larch and beech leaves. Freeze-drying had relatively little effect.

Larch needles lost their activity very quickly when aged aerobically for 8 months, whereas the activity of beech leaves decreased slowly. The activity of picked and fallen oak leaves increased dramatically during the first 1–2 weeks and then decreased, rapidly at first; after 8 months the activity was still comparable with the initial value.

There was no direct relationship between the activities of the extracts and the pH or the concentrations of polyphenols.

3.8 NEWMAN, A. C. D. (1967) Changes in phlogopites during their artificial alteration. *Clay Min.* **7**, 215–227.

When phlogopites containing only a little iron are altered with sodium tetraphenylboron solutions the vermiculite-like products contain fewer interlayer cations than the original micas. Structural formulae of the products are calculated from the chemical analyses, together with infra-red examination of the angular vibration band of water at 1650 cm^{-1} to distinguish between water of hydration and hydroxyl groups. The formulae obtained are consistent with the weight-loss curves and show that the products contain more than 4(OH,F) per formula unit. The interpretation of these formulae is that the silicate layers lose net negative charge by protonation of structural oxygen anions to form new hydroxyl groups.

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3.9 (PENNY, L. F.) & CATT, J. A. (1967) Stone orientation and other structural features of tills in East Yorkshire. *Geol. Mag.* **104**, 344–360.

Macrofabric (stone orientation) and microfabric studies of the four tills exposed in the coastal areas of East Yorkshire indicate that the regional direction of ice movement during both the Saale and Weichsel Glaciations was from north-east to south-west. The Saale (Basement) till was considerably modified by the advance of ice during the Weichsel Glaciation; in particular, the stones in the Basement were reorientated so that their long axes now lie at right angles to the direction of movement of the Weichsel ice sheet. The fabrics of the three Weichsel tills (Drab, Purple and Hessle) are alike, and it is suggested that all three were deposited from one composite ice sheet. The relationship of vertical joints in the Basement and Drab Tills to directions of ice movement is discussed; those in the Basement possibly originated as *ac* tension joints inherited from the parent ice, whereas some of those in the Drab are probably conjugate shear joints formed during post-depositional deformation of the till.

Soil Microbiology Department

THESIS

4.1 PATEL, J. J. (1967) Microorganisms in the rhizosphere and their interactions. Ph.D. Thesis, University of London.

GENERAL PAPERS

4.2 KLECZKOWSKA, J., NUTMAN, P. S., SKINNER, F. A. & (VINCENT, J. M.) (1968) The identification and classification of *Rhizobium*. In: *Identification methods for microbiologists, part B.* London: Academic Press. (In the press.)

4.3 ROUGHLEY, R. (1967) Preparation and use of legume seed inoculants. *Proceedings of 2nd Conference on Global Impacts of Applied Microbiology*. Wiley Inc. (In the press.)

4.4 SKINNER, F. A. (1967) The limits of microbial existence. In: Symposium: Anomolous aspects of biochemistry of possible significance in discussing the origins and distribution of life. *Proc. R. Soc. B.* (In the press.)

RESEARCH PAPERS

4.5 BROWN, M. E., JACKSON, R. M. & the late SUSAN K. BURLINGHAM (1968) Effects produced on tomato plants, *Lycopersicum esculentum*, by seed or root treatment with gibberellic acid and indole acetic acid. *J. exp. Bot.* (In the press.)

Tomato seeds or seedling roots were treated with 5·0, 0·5, 0·05, 0·005 and 0·0005 μg gibberellic acid and observations made on plant growth. Applying 5·0 μg to seed significantly accelerated growth of stems and leaves, decreased the number of flower buds formed on the first truss and lengthened the interval between bud appearance and petal fall (truss development time) by 1–4 days. Applying less than 5·0 μg did not alter early plant growth rates, but lengthened truss development time. Treating roots with 5·0, 0·5 and 0·05 μg significantly accelerated stem and leaf growth; stimulation was directly related to amount of GA3. 5·0 μg decreased bud number and lengthened first truss development time by 1–8 days. Less than 5·0 μg shortened truss development time by 1–4 days. IAA applied on its own had no effect and did not enhance the effect of

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gibberellic acid. Small amounts of GA3 added once to seeds or roots when leaf and flower initials are developing changed growth rates of stems, leaves and trusses as much as did repeated applications of larger quantities to more mature plants. The effects of small amounts of GA3 resemble those found after treating plants with cultures of *Azotobacter chroococcum*, which contain gibberellic acid and indole-acetic acid.

4.6 MOSSE, B. & (BOWEN, G. D.) (1968) A key to the recognition of some *Endogone* spore types. *Trans. Br. mycol. Soc.* (In the press.)

The main diagnostic features of nine *Endogone* spore types are described, with notes on some of their developmental stages. Seven of the nine spore types formed vesicular–arbuscular mycorrhiza with inoculated host plants.

4.7 MOSSE, B. & (BOWEN, G. D.) (1968) The distribution of *Endogone* spores in some Australian and New Zealand soils, and in an experimental field soil at Rothamsted. *Trans. Br. mycol. Soc.* (In the press.)

Some 250 Australian and New Zealand soils were examined. *Endogone* spores were usually more numerous and diverse in cultivated soils than under natural vegetation. It is suggested that intermittent root growth favours spore development. In a Rothamsted field soil given different manurial treatments (no manure, dung and mineral fertiliser) for more than 100 years spore populations differed considerably.

4.8 MOSSE, B. & (JONES, G. W.) (1968) Separation of *Endogone* spores from organic soil debris by differential sedimentation on gelatin columns. *Trans. Br. mycol. Soc.* (In the press.)

A technique is described for separating *Endogone* spores from organic soil debris, based on differential sedimentation rates of spores and debris in gelatin solutions of different concentrations.

4.9 NUTMAN, P. S. (1967) Symbiotic effectiveness in nodulated red clover. V. The *n* and *d* factors for ineffectiveness. *Heredity*. (In the press.)

Genetic evidence is presented for two recessive factors (*n* and *d*), either of which causes ineffective symbiosis in red clover. The factor *n* causes failure in nitrogen fixation in nodules produced by *Rhizobium trifolii* strains 0403, 30, 212 and probably also strain 220, but does not affect fixation in nodules produced by strains 1, 5, 32, 35 and 47. Nodule formation, number and sizes are unaffected by the *n* gene.

The recessive factor *d* causes failure in nitrogen fixation in nodules of red clover produced by strains 0403, 30, 35 and 220, but does not affect fixation in nodules produced by strains 1, 5, 32 and 212. Plants homozygous for *d* bear more but smaller nodules than heterozygotes, but this factor does not affect the time the first nodules appear on the roots.

The factors *n* and *d* and the factors i_1 and *ie* (Nutman, *Heredity* (1957) **11**, 157) are independent and non-allelic, and breeding results indicate that plants homozygous for more than one of these factors are poorly viable or non-viable.

Botany Department

GENERAL PAPERS

5.1 GOODMAN, P. J. (1967) What determines sugar-beet yield? 1. Soil and Weather. 2. Plant population and leaf area index. *Br. Sug. Beet Rev.* **35**, 115–117 and 171–172.

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5.2 HUMPHRIES, E. C. (1967) The dependence of photosynthesis on carbohydrate sinks: current concepts. *Proc. 1st International Symposium on Tropical Root Crops, Trinidad.* (In the press.)

5.3 WATSON, D. J. (1967) Physiological characteristics of the growth of sugar-beet crops on different soils. *I.I.R.B.* **2**, 225–231.

RESEARCH PAPERS

5.4 FORD, M. A. & THORNE, G. N. (1967) Effect of CO_2 concentration on growth of sugar beet, barley, kale and maize. *Ann. Bot.* **31**, 629–644.

Increasing the concentration of CO_2 in the air from the usual 300 to 1000 ppm in growth rooms with temperatures of 20° C during the 16-hour light period and 15° C during the 8-hour dark period increased the total dry weight of sugar beet, barley and kale by about 50%. A further increase in CO_2 concentration to 3300 ppm increased dry weight slightly more. These effects occurred with light intensities ranging from 3·7 to 11·6 cal dm^{-2} min^{-1} of visible radiation supplied by a mixture of fluorescent and tungsten lamps, and were only slightly greater with the brighter light. Extra CO_2 also increased leaf area, though relatively less than dry weight, and the number of barley shoots, but not of sugar-beet or kale leaves; it decreased leaf area ratio, specific leaf area and the ratio of tops to roots. Maize was taller with extra CO_2.

Net assimilation rates in 1000 and 3300 ppm CO_2 were about 20 and 30% respectively greater than in 300 ppm. Uptake of CO_2 in the light by complete tops and single leaves also increased with increase in CO_2 concentration. Photosynthesis of leaves of plants recently transferred to a new CO_2 concentration depended only on that concentration and not on the original one.

Doubling the light intensity from 3·7 to 7·7 cal dm^{-2} min^{-1} affected dry weight, leaf area, net assimilation rate, etc., similarly to a 10-fold increase in CO_2 concentration.

5.5 (GARVIE, D. W.) & WELBANK, P. J. (1967) A rasp-drum laboratory thresher and cleaner. *J. agric. Engng Res.* **12**, 229–232.

A machine is described for threshing and cleaning the grain of cereal samples from plot areas up to about 4 m^2, or containing up to 2 kg of grain. It comprises a rasp drum, sieves and blower, driven by electric motors, and a straw collector; it is readily movable. Threshing takes from about 5 minutes per sample.

5.6 HUMPHRIES, E. C. & DYSON, P. W. (1967) Effect on potato plants of a growth inhibitor, *N*-dimethylaminosuccinamic acid (B9), in the field. *Eur. Potato J.* **10**, 116–126.

Majestic seed potatoes ranging in size from 40 to 100 g were planted on 16 April, and some plants were sampled on 16 June just as tubers were forming, to estimate leaf area and dry matter of plant parts. Some plots were sprayed with the growth regulator *N*-dimethylaminosuccinamic acid (B9) at a concentration of either 1 g/l or 5 g/l. Plants were sampled again 2 weeks later and the same plots sprayed with B9. Further samples were taken at an interval of a month.

B9 had little effect on lamina weight because, although it decreased leaf area per plant, it increased dry weight per unit area. Stems were much shortened and their dry weight decreased. Tuber weight increased, especially soon after spraying. Total plant weight was not significantly affected by treatment. Leaf-area index of plants treated with 5 g/l was 20% less on 28 July. Treatment increased tuber number. Checking top growth made tubers grow faster at first.

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The growth regulator apparently had two distinct actions on the potato plant: (1) it increased the percentage of total dry matter that entered the tuber, and (2) it maintained the leaf-area index nearer the optimal value. Although spraying decreased leaf area, final yield of dry matter in the tubers was unaffected. Water content of the tubers was increased. The progeny of tubers from treated plants grew more slowly at first than progeny from untreated plants, apparently because the growth regulator persisted in the tubers.

5.7 HUMPHRIES, E. C. & DYSON, P. W. (1967) Effects of growth regulators CCC and B9 on some potato varieties. *Ann. appl. Biol.* **60**, 333–341.

The effects of CCC and B9 on the growth habit of potato differed between varieties. CCC diminished stem lengths and dry weight more than B9 because CCC was applied early when shoots emerged from the soil, and B9 about 3 weeks later when several leaves had formed.

In some varieties lateral stem growth was increased and in others decreased. There was an inverse relation between main stem and lateral stem growth, so that varieties with vigorous main-stem growth had poor lateral growth, and vice versa. The growth-regulators diminished leaf dry weight of main stem leaves less than leaf area, but the size of the changes depended on the variety. Both regulators lessened net assimilation rate. Net assimilation rate and dry matter per unit area of leaf were inversely related, possibly because accumulation of substances in leaves decreased photosynthesis.

Stolon dry weight was positively correlated with main-stem leaf area. There was a direct relation between stem length and tuber dry weight, suggesting that tuber initiation occurs at different stem lengths in different varieties. Tubers were initiated earliest in Epicure and latest in King Edward. Epicure had the greatest tuber weight and smallest stem length.

5.8 HUMPHRIES, E. C., WELBANK, P. J. & WILLIAMS, E. D. (1967) Interaction of CCC and water deficit on wheat yield. *Nature, Lond.* **215**, 782.

Grain yield of wheat treated with CCC increased in several experiments, although untreated plots did not lodge. At Woburn, where 2 in. of irrigation water increased yield by 10 cwt/acre, CCC had little effect on yields from irrigated plots, but it increased yield from unirrigated plots by 6 cwt/acre. These increases in yield were associated with more ear-bearing shoots and greater grain weight/ear. Plants treated with CCC lost fewer shoots than untreated plants during a dry spell when ears were emerging. Hand pulling recovered more roots from plots treated with CCC than from untreated plots, and CCC may have increased yield because it increased the amount of roots and enabled the plants to get more water during a critical period.

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

Leaf growth of kale seedlings was compared over a range of soil-moisture contents during a single drying cycle in several constant environments. With the particular soil and environments used, and when senescence effects were eliminated, relative leaf growth rate was a linear function of soil-moisture percentage in the range equivalent to pF 1·7–4·2. The relationship was independent of differences in the rate of change of soil moisture resulting from changes in atmospheric humidity or in the ratio of leaf area to amount of water in the soil mass. Nevertheless, small changes in the rate of water loss integrated over a period can have relatively large effects on yield.

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5.10 WELBANK, P. J., WITTS, K. J. & THORNE, G. N. (1968) Effect of radiation and temperature on efficiency of cereal leaves during grain growth. *Ann. Bot.* **32**, 79–95.

Grain : Leaf Ratio, G (the ratio of grain yield to Leaf Area Duration between ear emergence and maturity) in 15 experiments with wheat and barley in different seasons (Group A experiments) was highly correlated with mean daily radiation, R, mean daily temperature, T_{mean}, and mean daily maximum temperature, T_{max}, during the grain growth period. The regression of G on R accounted for 81% of the variance of G, and introducing T_{mean} to the regression significantly increased this to 88%. The regression of G on T_{max} alone accounted for 87%, perhaps because T_{max} effectively integrates radiation and temperature.

When R was varied artificially by shades in two experiments with wheat in different years (Group B experiments) the relationship between G and R was approximately linear in both, but the slope of the line was less in one year when R and temperatures were less than in the other. For this second year, when R and temperatures were about the middle of the ranges in Group A experiments, the calculated relationship agrees with the Group A results after correcting values of G for differences of T_{mean} from its value in the shading experiment. A formula relating G and R derived from the results of both Group B experiments and the observed correlation of R and temperature in the field, assuming that the regression of G on R depends on temperature, agrees with the relationship between G and R in the Group A experiments.

It is concluded that differences in radiation and temperature are about equally responsible for the differences in G found between seasons. The positive effect of temperature on G suggests that factors other than leaf photosynthesis, e.g. translocation rate or capacity of the grain to accept carbohydrate, are important in determining G.

5.11 WHEELER, A. W. (1968) Changes in auxins in expanding and senescent primary leaves of dwarf French bean (*Phaseolus vulgaris*). *J. exp. Bot.* **19**, 102–107.

A bound, unextractable auxin, or auxin precursor, in the primary leaves of dwarf French bean was converted to a form, probably indol-3-yl-acetic acid, extractable in ethyl acetate, by macerating leaves in phosphate buffer (pH 7·5) and incubating them at 37° C for 2 days in the presence of toluene or hibitane. Boiling the leaves before macerating and incubating them prevented the release of bound auxin. This bound auxin was also released when macerated leaves were hydrolysed with N-potassium hydroxide at 100° C for 2 hours. The amounts of free auxin and tryptophan in senescent primary leaves increased as their bound auxin and chlorophyll decreased. Removing the apical growing region immediately above the node bearing the primary leaves delayed their senescence and the conversion of their bound to free auxin.

Biochemistry Department

GENERAL PAPERS

6.1 HILL, J. M. & MANN, P. J. G. (1968) Some properties of plant diamine oxidase; a copper containing enzyme. In: *Recent aspects of nitrogen metabolism in plants.* Ed. E. J. Hewitt & C. V. Cutting, London: Academic Press, pp. 149–161.

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6.2 HOLDEN, M. (1967) The fungi of Whippendell Wood, Croxley Green. *Trans. Herts. nat. Hist. Soc. Fld Club* **26**, 194–199.

6.3 PIRIE, N. W. (1967) The construction of a lunar microcosm. In: *Life sciences research and lunar medicine. (Proc. 2nd LIL Symposium: Madrid 1966)* Ed. F. J. Malina, Oxford: Pergamon Press, pp. 39–50.

6.4 PIRIE, N. W. (1967) Production and use of leaf protein as a human food. *Kosmos* (*Dublin*), February, p. 7.

6.5 PIRIE, N. W. (1967) World protein supplies. *Proc. R. Soc. Med.* **60**, 1065–1066.

RESEARCH PAPERS

6.6 BACON, M. F., (OVEREND, W. G., LLOYD, P. H. & PEACOCKE, A. R.) (1967) The isolation, composition and physicochemical properties of deoxyribonucleic acid from *Bordetella pertussis*. *Archs Biochem. Biophys.* **118**, 352–361.

The percentage by weight of deoxyribonucleic acid in *Bordetella pertussis* is large. A method is described for isolating DNA from this bacterium in a relatively pure and undegraded form. DNA extracted from several strains usually had a base composition of 67·6% GC, but in one the composition was 57·5% GC. The two types of DNA were studied further: they contained no large amounts of bases other than the usual four, their light-scattering and sedimentation properties were very similar, and their thermal denaturation properties were consistent with the difference in base composition.

6.7 CLARKE, A. J., COX, P. M. & SHEPHERD, A. M. (1967) The chemical composition of the egg-shells of the potato cyst-nematode, *Heterodera rostochiensis* Woll. *Biochem. J.* **104**, 1056–1060.
(For summary see No. 8.7.)

6.8 CLARKE, A. J. & SHEPHERD, A. M. (1968) Hatching agents for the potato cyst-nematode, *Heterodera rostochiensis* Woll. *Ann. appl. Biol.* **61**, 139–149.
(For summary see No. 8.8.)

6.9 HILL, J. M. (1967) The inactivation of pea-seedling diamine oxidase by peroxidase and 1,5-diaminopentane. *Biochem. J.* **104**, 1048–1055.

Oxidative deamination of 1,5-diaminopentane by pea-seedling extracts, which contain diamine oxidase [diamine-oxygen oxidoreductase (deaminating), EC 1.4.3.6], was speeded by adding pyridoxal or pyridoxal phosphate. Evidence was obtained that pyridoxal does not activate the apoenzyme of diamine oxidase, but prevents the inactivation of the enzyme. This inactivation occurred only when 1,5-diaminopentane was the substrate and depended on a second thermolabile factor in the extract in addition to diamine oxidase. Purified diamine oxidase, when catalysing the oxidation of 1,5-diaminopentane, was rapidly inactivated in the presence of peroxidase. The inactivation was prevented not only by pyridoxal and pyridoxal phosphate but also by several unrelated compounds, including α-oxoglutarate, catechol and *o*-aminobenzaldehyde. It is suggested that peroxidase catalyses the further oxidation of the product of the oxidative deamination of 1,5-diaminopentane to a compound that inactivates diamine oxidase. The results diminish the relevance of previous evidence that plant diamine oxidase contains pyridoxal phosphate.

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6.10 PIERPOINT, W. S. (1968) Cytochrome oxidase and mitochondrial protein in extracts of leaves of *Nicotiana glutinosa* infected with tobacco mosaic virus. *J. exp. Bot.* (In the press.)

Leaves of *N. glutinosa* were inoculated with tobacco mosaic virus, and infection allowed to develop *in situ* or in discs cut from the leaves and floated on water or culture solution. Extracts, made from the leaves and discs when their respiration was greater than that of comparable uninfected tissue, contained amounts of protein N, chlorophyll, glycollic oxidase and mitochondrial protein N, similar to those in extracts from uninfected tissue, but slightly less cytochrome oxidase and considerably more polyphenoloxidase. No evidence was obtained for the view that the virus-induced respiration reflects an increase in the amount of mitochrondrial material.

Plant Pathology Department

BOOK

7.1 GREGORY, P. H. & MONTEITH, J. L. (1967) (editors) *Airborne microbes* (*Symp. Soc. gen. Microbiol. XVII*), Cambridge University Press. 385 pp.

THESIS

7.2 VARMA, A. (1967) Studies on red clover vein mosaic virus and some associated viruses. Ph.D. Thesis, University of London.

GENERAL PAPERS

7.3 BAWDEN, F. C. (1967) Improving the lot of farm people: trends and prospects from the standpoint of natural scientists. *Int. J. agr. Aff.* **5**, 115–129.

7.4 GREGORY, P. H. (1967) Plant diseases. In: *McGraw-Hill Yearbook of science & technology*, 1967, pp. 304–306.

7.5 GREGORY, P. H. (1967) Atmospheric microbial cloud systems. *Sci. Prog., Oxf.* **55**, 613–628.

7.6 GREGORY, P. H. (1967) Are fungi animals? *Trans. Herts. nat. Hist. Soc.* **26**, 153–155.

7.7 HIDE, G. A. (1967) The prevalence of pathogenic fungi on seed tubers. *Proceedings of the 4th British Insecticides and Fungicides Conference*, 1967, **1**, 265–268.

7.8 HIRST, J. M. (1968) The importance of tuber diseases. *Proceedings of the 4th British Insecticides and Fungicides Conference* **2**, 547–555.

7.9 KASSANIS, B. (1967) Tobacco necrosis virus and its satellite virus. *Nature, Lond.* **214**, 178.

7.10 MILNE, R. G. (1967) Plant viruses inside cells. *Sci. Prog., Oxf.* **55**, 203–222.

7.11 SALT, G. A. (1967) Pathology experiments on Sitka spruce seedlings. *Rep. Forest Res., Lond.*, 1966, 104–108.

7.12 SLOPE, D. B. (1966) Getting to grips with disease. *Arable Fmr* **1**, 20–23.

7.13 SLOPE, D. B. (1967) Disease problems of intensive cereal growing. *Ann. appl. Biol.* **59**, 317–319.

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

RESEARCH PAPERS

7.15 BAWDEN, F. C. & KASSANIS, B. (1968) The serological relationship between tobacco mosaic virus and cucumber viruses 3 and 4. *Virology*. (In the press.)

Contrary to reports in the U.S.A., the same degree of serological relationship between tobacco mosaic virus and cucumber viruses 3 and 4 was indicated whether tests were made with antisera to TMV or to the cucumber virus. Similarly, TMV and the bean form of tobacco mosaic consistently behaved like serotypes (remote serological relationship) and not strains (close serological relationship).

7.16 (CROSS, T., MACIVER, A. M.) & LACEY, J. (1968) The thermophilic actinomycetes in mouldy hay: *Micropolyspora faeni* sp. nova. *J. gen. Microbiol.* **50**, 351–359.

Taxonomic studies on the thermophilic oligosporic actinomycete chiefly responsible for the respiratory complaint Farmer's Lung support the view that the organism was incorrectly identified as *Thermopolyspora polyspora* Hens. The organism belongs to the genus *Micropolyspora* Lechevalier *et al.*, and is described as a new species, *Micropolyspora faeni*.

7.17 EBBELS, D. J. (1967) Effect of soil fumigants on *Fusarium* wilt and nodulation of peas (*Pisum sativum L.*). *Ann. appl. Biol.* **60**, 391–398.

Chloropicrin, dazomet, formaldehyde and "D-D" applied to soil all decreased the incidence of *Fusarium* wilt in a susceptible variety of pea grown in infested soil, but only chloropicrin and dazomet gave satisfactory control of the disease. All four fumigants decreased root nodulation, but did not adversely affect plant growth. Dazomet, formaldehyde and "D-D" probably decreased nodulation because of the soil nitrogen mineralised, whereas the almost complete suppression of the nodulation with chloropicrin probably reflects the lethal effect of this material on the *Rhizobium* bacteria.

7.18 FROST, R. R. & HARRISON, B. D. (1967) Comparative effects of temperature on the multiplication in tobacco leaves of two tobacco rattle viruses. *J. gen. Virology* **1**, 455–464.

Two kinds of assay, particle counts by electron microscopy and infectivity for leaves of *Phaseolus vulgaris*, were used to estimate the amounts of virus in extracts made from tobacco leaves kept at 14–34° C for 1–6 days after inoculation, and in extracts from uninoculated tip leaves sampled 14 days after the plants were inoculated. One, 2 and 6 days after inoculation virus isolate PRN was obtained in largest amount from leaves at 22°, 18° and 14° C, respectively. Isolate CAM showed the same trend, but equivalent temperatures were 4–6° C higher. At 14° C infectivity and particle numbers continued to increase between 1 and 6 days after inoculation, but at 30° C infectivity decreased after 1 day. At some temperatures the number of particles first increased and then decreased. For instance, at 26° C the number of particles of isolate CAM tripled between 1 and 2 days, and then decreased to $\frac{1}{100}$ or less between 2 and 6 days after inoculation. Temperature had only small effects on the ratio of long (*c.* 1900 Å) to short (mainly 450–900 Å) virus particles. Specific infectivity increased slightly when particle number was increasing and decreased greatly when particle number was decreasing. Specific infectivity sometimes decreased slightly before particle number. As with some small isometric plant viruses, the amount of

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tobacco rattle virus extracted from leaves apparently represents the resultant between synthesis and degradation, and the two processes are differently affected by temperature. At 14–22° C, but not at 26° C, isolate PRN produced necrotic lesions in inoculated leaves, whereas isolate CAM did not cause visible lesions. This difference seemed to have little effect on the changes in virus titre, but although isolate PRN multiplied optimally at a lower temperature than CAM, it was more stable *in vivo* at 26° C. Isolate PRN invaded uninoculated leaves only sporadically and accumulated in only small amounts. Isolate CAM readily invaded uninoculated leaves, where it reached its greatest concentration at 22° C.

7.19 HIRST, J. M., STEDMAN, O. J. (& HOGG, W. H.) (1967) Long-distance spore transport: Methods of measurement, vertical spore profiles and the detection of immigrant spores. *J. gen. Microbiol.* **48**, 329–355.

Airborne spores can be carried long distances, but little is known about the atmospheric transport processes involved or the rates at which spore clouds are depleted. Aircraft sampling is expensive and inevitably intermittent, and surface traps reveal only some of the processes involved. The best compromise is to combine ground and aircraft observations and to support both with detailed meteorological interpretation. Gravity-slide traps exposed for 1 day indicate the arrival of spores less precisely than moving-slide impactors, which therefore provide a more accurate starting time for estimating the past track of spores from air trajectories. Catches of *Puccinia graminis* uredospores from continental European sources illustrated how immigration depends on the movement of atmospheric pressure systems and the gradients within them, and suggested that, in addition to surface-air movement, winds at the 700 and 500 mb levels were important.

Aircraft of the Meteorological Research Flight, using suction impactors operating approximately isokinetically, sampled air in the lower troposphere, both to ascertain vertical spore profiles over land and to intercept immigrant *Puccinia graminis* uredospores over the English Channel. The vertical distribution of spores seemed to be determined in the same way as that of other aerosol particles; atmospheric turbulence was a major factor, and there were indications that wind shear, precipitation and surface deposition might be important. However, most spores are liberated periodically and so encounter different degrees of atmospheric turbulence, depending on the diurnal periodicity of their concentration near the ground. Concentrations of 10^4 spores/m^3 occurred at heights up to 1000 m and 10^2–10^3/m^3 at 3000 m. In unstable air, spore concentrations often declined roughly logarithmically with height, but layers of stable air were often associated with abrupt changes of concentration. Details of vertical spore profiles also depended on the history of both the temperature profile and the spore cloud. Such factors tended to affect all spore types similarly; but occasionally some components, e.g. *P. graminis* uredospores, showed unique vertical profiles. One such profile characterised by preferential "erosion" of the spore cloud from air near the surface may indicate travel remote from sources. Spores of plant pathogenic fungi were frequent in samples of air moving northward over the English Channel, but their viability was not tested.

7.20 HIRST, J. M., STEDMAN, O. J. (& HURST, G. W.) (1967) Long distance spore transport; vertical sections of spore clouds over the sea. *J. gen. Microbiol.* **48**, 357–377.

To measure the rate at which spore clouds were depleted over the sea, spores were collected with isokinetic suction impactors mounted in aircraft of the

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Meteorological Research Flight, Farnborough. Remote from sources able to replenish spore clouds, preferential deposition from the lower layers caused "erosion" of the base of vertical profiles of spore concentration, leaving maxima at heights between 500 and 1500 m. To determine vertical spore distributions throughout the largest possible distance downwind of the English coast, a saw-tooth flight plan of alternating ascent and descent was used. Of four flights, two encountered favourable weather, rain interfered with sampling on one and unexpected winds across the track converted another into an unintended but interesting cross-wind section of spore distribution.

Pollens and Cladosporium spores were counted as examples of large and small spores liberated typically by day, and a composite group of spores liberated in damp air was chosen as an indicator of spores liberated mostly at night. In two flights in fine weather maximum spore concentrations occurred hundreds of miles off-shore. Diagrams showing height, distance from the coast and lines of equal spore concentration ("isospores") demonstrated discrete clouds of each marker spore type. Pollen and Cladosporium clouds were centred at approximately the same distances from the coast, but the pollen was about 500 m lower, probably because the pollen grains sedimented faster. Maximum concentrations of the damp-air group sometimes coincided and sometimes alternated with the day-liberated groups. Known periodicities of these spores over land, surface air trajectories and previous weather suggested that the spore clouds the aircraft overtook over the North Sea were the residue of those produced from the British Isles on previous days or nights. Interpretation of the results was limited by meteorological uncertainties, the geographical complexity of probable source areas and perhaps most by changes in the number of spores crossing the coast at different times of the day, which prevented accurate measurement of rates of spore deposition.

Spores of many species were recognised over the North Sea. The plant pathogens included established distant migrants, such as uredospores of *Puccinia graminis*, which apparently originated east of the Baltic. The viability of the spores was not tested, but it seems safe to assume that distant transport is both frequent and extensive, and probably important in temperate latitudes during summer.

7.21 KASSANIS, B. & MCCARTHY, D. (1967) The quality of virus as affected by the ambient temperature. *J. gen. Virol.* **1**, 425–440.

Dolichos enation mosaic virus is a serotype of tobacco mosaic virus infecting leguminous plants; it produces a large proportion of particles shorter than 3000 Å, the accepted length of infective tobacco mosaic virus. A new strain of dolichos enation mosaic virus isolated from a single necrotic lesion on French bean caused local and systemic necrosis in French-bean plants. It produced many more defective particles than the parent strain when infected plants were kept at 20° C, but not at temperatures above 32° C. Both strains multiplied faster at 32° C than at 20° C, but the effect of increasing temperature was greater with the new strain. The effect on the new strain seemed greater when virus content was assayed by infectivity tests than when it was assayed serologically, suggesting that infectivity per unit weight of virus was also greater at 32° C than at 20° C. No evidence was found that leaves infected with the new strain contained free infective RNA.

The ultraviolet absorption spectra of purified preparations of the new strain produced at 20° C had a greater optical density at 280 mμ than at 260 mμ, whereas the parent strain had greater density at 260 mμ, showing that some of the particles of the new strain were without RNA. The type of particles pro-

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duced by the two strains differed when purified preparations in 0·06*M*-phosphate buffer at pH 8 were subjected to analytical ultracentrifugation in sucrose gradient columns or fractionation through agar columns. When produced in plants at 20° C the new strain consisted mainly of ring-like particles, virus protein, some free RNA and very few infective particles. By contrast, the parent strain consisted mainly of infective virus and broken particles of various lengths, of which a particle 400 Å long was plentiful enough to give a peak in the analytical centrifuge and a zone in sucrose gradient columns. The new strain produced in plants at 32–36° C did not differ in appearance or infectivity from the parent strain. The distribution of particle lengths in sprayed droplets, measured in the electron microscope, confirmed the difference found by other means between the type of particle in the two strains.

Changing the pH value of a purified preparation of the new strain (produced at 20° C) from 5·2 to 8 released some RNA in amounts suggesting that about a third of the particles in the preparation released their RNA.

7.22 KASSANIS, B. & VARMA, A. (1967) The production of virus-free clones of some British potato varieties. *Ann. appl. Biol.* **59**, 447–450.

Virus-free clones of some British potato varieties, of which all commercial stocks are infected, were obtained by culturing apical meristems of sprouts on tubers. The variety Golden Wonder was freed from potato virus A, Arran Comet from potato virus X, and Epicure, Orion and Sharpe's Express from potato virus S. Of the 196 meristems cultured, 41 (21%) grew and 20 of these developed into plants, of which 19 were virus-free. More of the excised meristems grew when the first leaf primordium was included than when not, and its inclusion seemed not to increase the chances of the progeny being infected.

7.23 KLECZKOWSKI, A. & MCLAREN, A. D. (1967) Inactivation of infectivity of RNA of tobacco mosaic virus during ultraviolet irradiation of the whole virus at two wavelengths. *J. gen. Virol.* **1**, 441–448.

Loss of infectivity by tobacco mosaic virus exposed to ultraviolet radiation seemed to result entirely from changes in the RNA of the virus. Any changes that may have occurred in the virus protein seemed not to contribute to loss of infectivity, but there was an interaction between the protein and the RNA because free RNA was equally sensitive to inactivation by absorbed radiation energy of any wavelength (i.e. the extent of inactivation depended entirely on the number of absorbed quanta irrespective of the wavelength), whereas inside the virus the RNA was about 24 times more sensitive to inactivation at 230 mμ than at 280 mμ. Inside the virus the RNA seemed to be largely protected by the protein from damage by radiation of 280 mμ and 254 mμ, but not of 230 mμ, to which it was about as sensitive as when free.

Ultraviolet irradiation at any wavelength caused at least two kinds of damage to free RNA, one of which was photoreversible and did not occur in the RNA irradiated when inside the virus.

7.24 LACEY, J. (1967) The role of water in the spread of *Phytophthora infestans* in the potato crop. *Ann. appl. Biol.* **59**, 245–255.

During falls of rain before 5% of the haulm was destroyed by blight most rain-water was deposited on soil at the bottom of the ridge, and least at the top in crops of King Edward, Majestic and Up-to-Date potatoes. Afterwards less water was trapped half-way up the side of the ridge than above or below. Water was also channelled down the stems and, while these were upright, was deposited

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in the channel often formed around the stem bases by wind movement. Fewer than 500 sporangia/ml were seen in water collected when blight was present in the crop.

Growing tubers of Ulster Ensign and King Edward, inoculated with *P. infestans*, infected healthy tubers less than 1·3 cm away, when the soil-water content was greater than 20%, and sporulation on the inoculated tubers was maximal. Similarly, inoculated Up-to-Date and Majestic tubers sporulated less abundantly and failed to infect healthy tubers.

Sporulation also occurred on inoculated seed tubers, although infection of the haulm from these tubers could not be confirmed. Water may move from the seed-tuber region to the furrows in suitable conditions.

7.25 LACEY, J. (1967) Susceptibility of potato tubers to infection by *Phytophthora infestans*. *Ann. appl. Biol.* **59**, 257–264.

Phytophthora infestans infects King Edward potato tubers more readily through inoculated eyes than through lenticels, but more lenticels than eyes became infected when whole tubers were sprayed with inoculum. The resistance of lenticels but not of eyes increased as tubers aged. The spores did not infect through intact periderm. The likelihood of tubers on plants grown in pots becoming infected by sporangial suspension poured on to the soil increased on tubers closer to the soil surface, the stem or the side of the pot. Naturally infected tubers, and those sprayed with sporangial suspension, had most eyes infected at the rose end, and most lenticels infected on the middle region of the tuber. Of naturally infected tubers, on which the site of infection could be identified, most were infected through eyes at the rose end.

7.26 LACEY, J. (1967) Mastigosporium leaf fleck of perennial ryegrass. *Pl. Path.* **16**, 48.

Infection of *Lolium perenne* by *Mastigosporium album* is recorded for the first time.

7.27 LACEY, J. (1968) The microflora of fodders associated with bovine respiratory disease. *J. gen. Microbiol.* **50**. (In the press.)

The microflora of samples of fodder fed to cattle on 41 farms where some cattle suffered respiratory disease was comparable with that previously reported in hays. Of the 59 samples of fodder examined, 30 coming from 29 different farms were very mouldy and comparable with Farmer's Lung type hay in being rich in *Micropolyspora faeni* and *Thermoactinomyces vulgaris*. The remaining samples were classified as either good or mouldy in almost equal numbers.

7.28 LAPWOOD, D. H. (1967) Laboratory assessments of the susceptibility of potato tubers to infection by blight (*Phytophthora infestans*). *Eur. Potato J.* **10**, 127–135.

The tubers of potato varieties that differ in field susceptibility to *Phytophthora infestans* also differed when wound-free tubers, grown in peat, were sprayed with spore suspensions. Those very susceptible in the field not only gave the most infected tubers but the area of rotted tissue per infection was more than in resistant varieties.

The fungus penetrated the tubers through eyes or lenticels, and with few exceptions the total numbers of penetrations decreased with increasing field-resistance of the variety. Tubers of some resistant varieties developed many infections, but most of the lesions were arrested when still necrotic threads or after limited rotting of tissues.

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With most of the 15 varieties tested, laboratory and field assessments of resistance were well correlated, but Up-to-Date, King Edward and Arran Pilot were more resistant than expected from field assessments and Arran Viking less.

7.29 LAPWOOD, D. H. (1968) Observations on the infection of potato leaves by *Phytophthora infestans*. *Trans. Br. mycol. Soc.* **51**, (2).

The time taken at 15° C for spores of *Phytophthora infestans* to infect leaves of nine potato varieties was estimated by drying leaves at different times after they were inoculated.

E.T. 50 values (time of drying which gave 50% replicates infected) differed slightly between varieties, but were the same for Bintje, which is field-susceptible, as for Ackersegen and Populair, which are resistant. Host reaction depended on how long the leaves were wet, and differed with the resistance of the variety. Lesions on field-susceptible varieties were large 3 days after inoculation, but small on resistant varieties.

Bintje and Pimpernel differed most, both in host reaction and E.T. 50, and diluting the inocula accentuated the difference.

Observation of spore germination in droplets on these two varieties showed a similar pattern of zoospore release and swimming time. Zoospores behaved differently on the leaf surface of Pimpernel and Bintje; on Pimpernel few encysted zoospores produced appressoria immediately they germinated, but instead produced long germ tubes before penetration. This difference in spore behaviour may help to explain the difference in E.T. 50 value between the varieties.

7.30 LAPWOOD, D. H. & (LEWIS, B. G.) (1967) Observations on the timing of irrigation and the incidence of potato common scab (*Streptomyces scabies*) *Pl. Path.* **16**, 131–135.

Common scab (*Streptomyces scabies*) on majestic potato tubers was checked by irrigation maintaining the soil at saturation ("field capacity") throughout the growing season more than it was by irrigating only before the first tubers had grown to $\frac{1}{4}$–$\frac{1}{2}$ in. diameter.

The stage of the tubers when irrigation was started or stopped affected the distribution of scab lesions on their surfaces, and infections were rare on tissue formed when soil was saturated.

7.31 LAPWOOD, D. H., HIDE, G. A. & HIRST, J. M. (1967) An effect of soil compaction on the incidence of potato coiled sprout. *Pl. Path.* **16**, 61–63.

The incidence of coiled sprout in majestic potatoes was increased by chitting the seed, planting deeply and compacting the soil.

Stem bases of plants from unchitted seed produced coiled stems only in rolled soil, and then only few. Coils were most abundant with plants from chitted seed in rolled soil. Rolling the soil increased the incidence of coiling and fasciation more than did chitting.

Chitted seed planted 1 in. deep produced very few coils, even in rolled soil. Not all coils showed lesions, but *Verticillium nubilum* Pethybr. was frequently isolated from lesions.

7.32 MCCARTHY, D. & WOODS, R. D. (1968) Electron microscopic observation on dolichos enation mosaic virus. *J. gen. Virol.* **2**, 9–12.

Sap from plants infected with a strain (NDEMV) of dolichos enation mosaic virus (DEMV) contains many ringlike particles, but few particles of normal

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lengths (*c.* 300 mμ). In purified preparations the mean length of normal particles of NDEMV was 300 mμ and that of DEMV, 286 mμ, though there was no difference in the pitch of the primary helix. Staining with uranyl formate clearly revealed the fine structure of these particles, and it penetrated the ring-like particles to the expected position of the ribonucleic acid.

7.33 McLaren, G. D. (1967) Infectivity changes in preparations from plants infected with tobacco mosaic virus. *J. gen. Virol.* **1**, 243–245.

The infectivity of RNA extracted by phenol from cell-free preparations of tobacco leaves infected with tobacco mosaic virus increased not only after incubating the preparations for 2–3 hours at 20–22° C but also at 2° C, and still more after freezing and thawing. Thus, the increased infectivity after incubating at 20–22° C cannot be taken as evidence of *in vitro* virus multiplication.

7.34 Milne, R. G. (1967) *In vitro* crystallisation of tobacco mosaic virus in the presence of basic proteins. *J. gen. Virol.* **1**, 403–404.

TMV particles form true three-dimensional crystals in infected plants, but such crystals have not been produced *in vitro*. It is here reported that small but truly crystalline arrays of TMV particles can be formed *in vitro* by adding basic proteins to salt-free TMV solutions. The protein and TMV combine in what is probably a salt-like interaction of oppositely charged particles.

7.35 McLaren, A. D. & Kleczkowski, A. (1967) Some gross changes in particles of tobacco mosaic virus caused by large doses of ultraviolet radiation. *J. gen. Virol.* **1**, 391–394.

Irradiating the virus with doses much larger than needed to inactivate infectivity denatures protein subunits so that they no longer conform to the structure of virus particles and fall out. This erosion in the walls finally breaks the particles into amorphous masses. The quantum yield for denaturation of the protein subunit is about 0·0003.

7.36 Raw, F., Jones, M. G. & Gregory, P. H. (1968) The food of female wheat-bulb flies (*Leptohylemyia coarctata* (Fall.)). *Pl. Path.* **17**, 23–25.
(For summary see No. 10.23)

7.37 Varma, A., Gibbs, A. J., Woods, R. D. & Finch, J. T. (1968) Some observations on the structure of the filamentous particles of several plant viruses. *J. gen. Virol.* **2**, 107–114.

Several plant viruses with filamentous particles ranging in modal lengths from 0·48 to 1·25 μ were negatively stained with uranyl formate, examined in the electron microscope and the electron micrographs analysed in various ways. The particles of all the viruses were helically constructed with a basic pitch of 33–37 Å (mean 34 Å), but could be separated into groups by other features of their particles. Various measurements of the particles of five of the viruses suggest that there were 10–14 subunits in each turn of the basic helix of their particles.

All plant viruses with elongated particles seem to fall into one of two groups; those with modal lengths of 0·3 μ or shorter seem rigid and have a basic helix of pitch 23–25 Å, and those with longer particles are filamentous and have a basic helix of pitch 33–37 Å.

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7.38 WATSON, M. A. & OKUSANYA, B. A. M. (1967) Studies on the transmission of groundnut rosette virus by *Aphis craccivora* Koch. *Ann. appl. Biol.* **60**, 199–208.

Four strains of groundnut rosette virus were transmitted by a race of *Aphis craccivora* (Koch) from groundnut in Nigeria. Two of these strains, both from East Africa, were transmitted only by *A. craccivora* from Kenya. A fifth isolate, from Nigeria, was not transmissible by either race. The two races of aphids have been shown elsewhere to be distinct biotypes.

Most *A. craccivora* needed longer than 24 hours feeding on infected groundnuts to acquire virus, and many needed 2–3 days of feeding on healthy plants to cause infection, even after several days on infected plants. The delays partly reflect the slow uptake of virus and possibly a period needed for virus to multiply in the aphid, but some may be because the test plants resist infection.

In consecutive feeding experiments, Natal Common variety could be infected soon after aphids had left the source of virus, but a more resistant Nigerian variety sometimes needed several days. The frequency of inoculation by aphids, or the concentration of virus in the inocula or both, increased with time, but the times at which aphids were able to infect plants also depended on the variety of test plant.

Nematology Department

BOOK

8.1 JONES, F. G. W. & DUNNING, R. A. (1968) Sugar beet pests. *Bull. Minist. Agric. Fish Fd, Lond.* No. 162 (revised) London: H.M.S.O.

GENERAL PAPERS

8.2 CORBETT, D. C. M. (1968) *Cercospora* leafspots. In: *Pest control in groundnuts*. PANS Manual No. 2, pp. 55–60.

8.3 GREEN, C. D. (1967) Nematodes. *Jl R. agric. Soc.* **128**, 206–216.

8.4 JONES, F. G. W. (1968) The biological and economic effects of nematodes on crops. *Sch. Sci. Rev.* (In the press.)

8.5 JONES, F. G. W. & PARROTT, D. M. (1968) Potato production using resistant varieties on land infested with potato cyst eelworm. *Outl. Agric*, **5**, 215–222.

8.6 WHITEHEAD, A. G. (1968) Nematodes. In: *Pests of coffee*. Ed. R. H. le Pelley, London: Longmans Green.

RESEARCH PAPERS

8.7 CLARKE, A. J., COX, P. M. & SHEPHERD, A. M. (1967) The chemical composition of the egg-shells of the potato cyst-nematode, *Heterodera rostochiensis* Woll. *Biochem. J.* **104**, 1056–1060.

Eggs of the potato cyst-nematode (*Heterodera rostochiensis* Woll.) were opened by ultrasonic vibration and the egg-shells separated from the released larvae by centrifuging in a density gradient. About 1 mg of dried egg-shells was obtained from 1000 cysts. The major constituent of the egg-shells was protein (59%, calculated from nitrogen content). About 80% of the egg-shells dissolved on acid hydrolysis. Of the 18 amino acids found, proline was most abundant, and, with aspartic acid, glycine and serine, made up about 64% by weight of the total

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amino acids. The small amounts of aromatic and sulphur-containing amino acids, and the presence of hydroxy-proline, indicate a collagen-like protein. The egg-shells gave a positive van Wisselingh colour test for chitin, and glucosamine was detected in their acid hydrolysate by chromatography. The glucosamine content of the egg-shells, determined by the Elson–Morgan colorimetric method, was 7%, corresponding to about 9% chitin. Dried egg-shells contained about 7% of lipid, 6% of carbohydrate and 3% of ash. Polyphenols (3% by weight of the egg-shells) were detected in the acid hydrolysates. Neither the collagen nor the chitin showed evidence of crystallinity when examined by X-ray diffraction.

8.8 CLARKE, A. J. & SHEPHERD, A. M. (1968) Hatching agents for the potato cyst-nematode, *Heterodera rostochiensis* Woll. *Ann. appl. Biol.* **61**, 139–149.

Of the 444 compounds tested for ability to stimulate eggs of *Heterodera rostochiensis* to hatch, 45 did so to various extents. Many compounds that hatched *H. schachtii* Schm. eggs did not hatch *H. rostochiensis* eggs. The most effective compounds with *H. rostochiensis* were picrolonic acid, anhydrotetronic acid and vanadates. Tests with analogues of picrolonic and anhydrotetronic acids suggested some structures that may be concerned in hatching *H. rostochiensis* and *H. schachtii*. The simple analogues hatched the eggs of *H. schachtii* but not of *H. rostochiensis*. Suitably placed polarisable atoms seemed an essential feature. Picrolonic acid contains pairs of polarisable atoms about 4 and 6·7 Å apart that may respectively be associated with the hatching of *H. schachtii* and *H. rostochiensis*. Other features of the more active hatching agents were a *cis* and coplanar arrangement of the two polarisable atoms with respect to the rest of the molecule.

8.9 DONCASTER, C. C. & SHEPHERD, A. M. (1967) The behaviour of second-stage *Heterodera rostochiensis* larvae leading to their emergence from the egg. *Nematologica* **13**, 476–478.

Potato-root exudates stimulate second-stage larvae to use their mouth stylets to cut a slit in the egg-shell. Some larvae move slightly within the egg even before such stimulation, but after that a sequence of activity starts with moving about, followed by pharyngeal gland secretion and stylet thrusting. Stimulation by sodium metavanadate causes the larvae to move vigorously and thrust their stylets, but their activity is poorly co-ordinated and larvae emerge by pushing through the egg-shell, which becomes softened, perhaps by the metavanadate. Gland secretions seem not to be important for egg hatch in this species.

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

Aggregation of *D. dipsaci* in deep water seems to depend initially on external factors to bring the nematodes close to one another. Clumping does not depend on sensory attraction. A proportion of the nematodes present must be moving to form clumps by random interlocking.

8.11 GREEN, C. D. (1967) Preparation of nematodes for examination under the Stereoscan Electron Microscope and examples of photomicrographs obtained. *Nematologica* **13**, 279–282.

The Cambridge Stereoscan Electron Microscope allows nematode cuticle to be examined in detail. Specimens must not be covered, and all volatile liquid must be removed. The least-distorted specimens were those impregnated with anhy-

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drous glycerol or polyethylene glycol (400), the excess of which was drained from the surface before they were mounted and plated with gold–palladium in a vacuum chamber.

8.12 GREET, D. N. (1967) The effect of soil fumigation on the growth of sugar beet. *Pl. Path.* **16**, 111–116.

In four trials in sandy soils where beet had previously grown poorly only slight improvements in growth and yield were obtained after fumigating the soil with dichloropropene–dichloropropane mixture or chloropicrin. Sugar yields were decreased by "D-D". Neither the needle nematode (*Longidorus attenuatus*) nor stubby root nematodes (*Trichodorus* spp.) were abundant at the four sites.

8.13 HOOPER, D. J. & COOKE, D. A. (1967) Some observations on *Anomyctus xenurus* Allen, 1940. *Nematologica* **13**, 320–321.

Specimens of *Anomyctus xenurus* from a sandy soil in Eastern England are compared with syntypes, and the description of the species is augmented. The anterior part of the spear is slightly curved and unevenly thickened. The oral opening of the English specimens appears hexaradiate in face view.

8.14 (JAIRAJPURI, M. S.) & HOOPER, D. J. (1968) A review of the genus *Aulolaimus* de Man 1880 (Axonolaimidae: Aulolaiminae n. subfam.) with notes on the synonymy of the genus *Pandurinema* Timm, 1957. *J. Helminth.* **42**. (In the press.)

Aulolaimus oxycephalus de Man, 1880, is redescribed. The definition of the family Axonolaimidae is amended and Aulolaiminae n. subfam. is proposed to accommodate *Aulolaimus* de Man, 1880 and *Pseudoaulolaimus* Imamura, 1931. *Pandurinema* Timm, 1957 is made a synonym of *Aulolaimus* and *Aulolaimus filiformis* (Timm, 1957) n. comb. is also redescribed.

8.15 JONES, F. G. W. (1967) Frequency of new females (cysts) in single cyst cultures of *Heterodera rostochiensis*, their relevance to the inheritance of ability to overcome resistance and to the frequency of mating. *Nematologica* **13**, 469–472.

The ability of progeny in cysts raised on eelworm-resistant potato hybrids bred ex *andigena* to form new cysts on the same hybrids tends to conform to the hypothesis that larvae able to become females (i.e. to form cysts) are double recessives and that they are mated several times.

8.16 JONES, F. G. W., PARROTT, D. M. & ROSS, G. J. S. (1967) The population genetics of the potato cyst-nematode *Heterodera rostochiensis*: mathematical models to simulate the effects of growing eelworm-resistant potatoes bred from *Solanum tuberosum* ssp. *andigena*. *Ann. appl. Biol.* **60**, 151–171.

To follow population changes when potato varieties with resistance to *Heterodera rostochiensis* derived from *Solanum tuberosum* ssp. *andigena* were grown on infested land, a computer program was written including three mathematical relationships: (1) a law relating multiplication to pre-cropping density; (2) two mathematical models of inheritance of ability to overcome resistance; (3) a law relating the proportion of larvae able to become female to pre-cropping population density. The programme also included four parameters: (1) the maximum possible reproductive rate; (2) the fraction of the population (eggs) not participating in reproduction when potatoes are grown and carried over to the

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following year unchanged; (3) the fraction carried over annually when other crops are grown; (4) the frequency of larvae able to become female in the population initially. Population density was measured relative to the equilibrium density, and was therefore independent of the units in which density is usually measured.

After supplying a range of parameters for all the above to include those likely to be encountered in practice, the changes expected (*a*) in the frequency of larvae able to become female in the roots of resistant varieties, and (*b*) in the population density were computed for resistant varieties grown continuously or alternately with susceptible varieties in crop rotations of different lengths. Because well-established field populations are relatively dense, observed reproductive rates are small and rarely approach the maximum possible. Reproductive rate is therefore a relatively unimportant determinant of genetic change. The fraction of the population carried over to the following year is more important because it affects the length of a crop rotation necessary to make yield losses acceptably small, determines what the multiplication rate will be and influences the speed of genetic change by providing a reservoir of initial type males to backcross with any genetically different females that may develop on the roots of resistant plants.

When the law relating the proportion of larvae able to become female to pre-cropping population density was included in the computations it had little effect initially, but later, after several generations, it delayed genetic change.

Two field experiments, one by Huijsman (1961) another by Williams (1958) and Cole & Howard (1962a), provide some of the variables needed to compute trends in population density. Best-fitting variables were computed for the results of these experiments by the method of maximum likelihood. The computed parameters for one experiment were not very realistic, but those for the other were in line with what would be expected in practice and tended to favour the hypothesis that larvae able to become female in the roots of resistant plants are double recessives.

The computations lead us to suggest that the best policy for potato growers who have fields suitable for resistant varieties is to alternate resistant with susceptible varieties in a crop rotation containing potatoes every 3 or 4 years.

8.17 JONES, F. G. W., PARROTT, D. M. & WILLIAMS, T. D. (1967) The yield of potatoes resistant to *Heterodera rostochiensis* on infested land. *Nematologica* **13**, 301–310.

Yields of a resistant potato variety bred from *Solanum tuberosum* ssp. *andigena* were adversely affected when their roots were invaded by *H. rostochiensis* larvae of a pathotype unable to multiply in them. Yields were inversely proportional to pre-cropping population densities. Populations decreased slowly when the resistant variety was grown continuously, but showed a tendency to increase after 4–5 years. There was some evidence that pathotypes 1 and 1, 2 increased slightly (pathotypes B and C of other British workers), whereas pathotype 2 (pathotype A) remained much the same. The dominant gene for resistance from *Solanum tuberosum* ssp. *andigena*, the one from *S. multidissectum* and both together, seemed to confer some tolerance to the injury caused by root invasion. After fumigating soil with methyl bromide potato yields were increased so much that pathogens other than *H. rostochiensis* were probably also controlled. Although a significant linear relationship could be fitted to the relationship between the yield of an experimental resistant variety bred from *S. tuberosum* ssp. *andigena* and the logarithm of the pre-cropping population density, the real relationship is probably sigmoid.

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8.18 SANTOS, M. S. N. DE A. (1967) *Meloidogyne ardenensis* n. sp. (Nematoda: Heteroderidae), a new British species of root-knot nematode. *Nematologica* **13**, 593–598.

Meloidogyne ardenensis n. sp. is described from *Vinca minor* and other woodland plants in England. It differs from other described species in the perineal pattern, the forward position of the excretory pore and the fairly long stylet of the female, in the truncate cone-shaped head with three or four annules behind the head cap in the male, and in having the excretory pore anterior to the hemizonid in the larva.

8.19 SHEPHERD, A. M. & COX, P. M. (1967) Observations on periodicity of hatching of eggs of the potato cyst-nematode, *Heterodera rostochiensis* Woll. *Ann. appl. Biol.* **60**, 143–150.

Soil containing new-generation cysts of *Heterodera rostochiensis* was taken from the field at monthly intervals during late summer and autumn and kept in various conditions for up to a year. The number of eggs that hatched in the stored cysts was compared each month with the number that hatched in cysts taken directly from the field. Eggs did not hatch readily when stimulated during the late autumn and early winter, although more did so in cysts taken from the field before August than after. A few more eggs hatched in cysts stored in air-dried soil than in cysts stored in moist soil. Some cysts were kept at 15 or 20° C continuously and others at 5°, 15° or 30° C for 6 weeks, followed by 20° C continuously. Storage at 30° C caused eggs to hatch sooner, but otherwise the temperature of storage had little effect on hatch at any time of the year. Warmth also increased the hatch of *H. cruciferae* sooner, and some synthetic hatching agents did so with both of these species. When freed from new cysts, more eggs of *H. rostochiensis* hatched than in intact cysts, and hatch was further increased when the fragments of tanned cyst-wall were left with the freed eggs. Puncturing the cyst-wall of new brown cysts had little effect on the hatch in potato-root diffusate. Like eggs in new cysts, those in 1-year-old cysts stored out of doors ceased to hatch during the autumn and winter. The term "dormancy" is inadequate to describe the inability of eggs of *H. rostochiensis* and other *Heterodera* spp. to hatch in the appropriate stimulant, and the term "facultative diapause" as applied to insects better fits the phenomenon.

8.20 TRUDGILL, D. L. (1967) The effect of environment on sex determination in *Heterodera rostochiensis* Woll. *Nematologica* **13**, 263–273.

The conditions to which larvae of *H. rostochiensis* were exposed in host-plant roots determined the sex ratio of the adults. The proportion of larvae becoming female decreased with increasing nematode density, and the sex ratio was unity with about 10 nematodes per cm of root. Apparently second-stage larvae can become females only when provided with giant cells of a minimum size and nutrient content. As the density of invading larvae increases, fewer find sites to contain such giant cells and an increasing proportion become males. Most larvae that invade lateral roots become males.

8.21 TRUDGILL, D. L., WEBSTER, J. M. & PARROTT, D. M. (1967) The effect of resistant solanaceous plants on the sex ratio of *Heterodera rostochiensis* and the use of the sex ratio to assess the frequency and genetic constitution of pathotypes. *Ann. appl. Biol.* **60**, 421–428.

The sex ratios of two *Heterodera rostochiensis* populations were compared on 15 solanaceous plants. Larvae did not mature in the roots of *Atropa belladonna*, *Datura stramonium* or *Nicotiana tabacum*, but adults were produced on the

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other plants, on some only males, and on others males and females. With two other populations, but not with a third, the percentage of larvae that become female on a potato hybrid with a dominant gene for resistance derived from *Solanum tuberosum* ssp. *andigena* increased during successive generations on the hybrid in accordance with the hypothesis that such larvae are double recessives. Fewer larvae became adult in plants with two dominant genes for resistance than in plants with one, and such plants probably exerted selection on both males and females. A population from St. Brelades (Jersey) produced fewer females and more males on the susceptible variety Arran Banner than did either the Thorney (Cambs.) or Aberystwyth populations. A much greater percentage of larvae from the St. Brelades population became female on an ex *andigena* hybrid derived from CPC 1690 than on one derived from CPC 1685.

8.22 WEBSTER, J. M. (1967) The influence of plant growth substances and their inhibitors on the host–parasite relationships of *Aphelenchoides ritzemabosi* in culture. *Nematologica* **13**, 257–262.

The multiplication of *Aphelenchoides ritzemabosi* on lucerne seedlings grown aseptically on nutrient agar medium without 2,4-dichlorophenoxyacetic acid was significantly increased by kinetin, gibberellic acid, indole-3-acetic acid (IAA) and by the IAA precursor tryptophane. The double treatments gibberellic acid–IAA and gibberellic acid–tryptophane increased multiplication significantly more than gibberellic acid alone. (2-Chloroethyl) trimethylammonium chloride (a gibberellic acid antagonist), 7-azo-indole (IAA inhibitor) and 2-hydroxy-5-nitro-benzyl bromide (tryptophane inhibitor) decreased multiplication, significantly so in the presence of gibberellic acid. The nematodes multiplied fastest when plant growth or cell activity was greatest. It is suggested that the nematodes secrete proteolytic enzymes that release from the plant tissues amino acids such as tryptophane (precursor of IAA) and substances such as gibberellic acid, which stimulate cell activity and growth and provide conditions favouring nematode multiplication.

8.23 WEBSTER, J. M. & GREET, D. N. (1967) The effect of a host crop and cultivations on the rate that *Ditylenchus dipsaci* reinfested a partially sterilised area of land. *Nematologica* **13**, 295–300.

A clay-loam soil infested with *Ditylenchus dipsaci* was fumigated with methyl bromide and its reinfestation from adjacent unfumigated land studied. Cultivation across fumigated and unfumigated plots did not increase the rate of reinfestation. Fallow plots were invaded more slowly than plots carrying a host crop (the susceptible oat, variety Powys). Movement from unfumigated fallow plots was faster at first than from those plots carrying oats, but later, after nematodes had multiplied in the oats, was faster from plots carrying oats.

8.24 WHITEHEAD, A. G. (1968) Taxonomy of *Meloidogyne* Goeldi, 1887 (Nematoda: Heteroderidae) with descriptions of four new species. *Trans. zool. Soc. Lond.* **32**. (In the press.)

A taxonomic study confirmed the morphological distinctness of 21 species of Meloidogyne, including three new species from Africa and one from India. *M. inornata* Lordello, 1956, and *M. tadshikistanica* Kirjanova and Ivanova, 1965, may be distinct species, but *M. poghossianae* Kirjanova, 1963, is a *species inquirenda*. Keys to identify adults and larvae to their species are given. Types are designated for *M. exigua* Goeldi, 1887, *M. arenaria* (Neal, 1889) Chitwood, 1949, *M. incognita* (Kofoid & White, 1919) Chitwood, 1949, *M. javanica* (Treub, 1885) Chitwood, 1949 and *M. thamesi* Chitwood in Chitwood, Specht & Havis,

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1952 (Goodey, 1963). The genus *Hypsoperine* Sledge & Golden, 1964, is rejected and two of its species renamed *M. graminis* (Sledge & Golden, 1964) n. comb. and *M. spartinae* (Rau & Fassuliotis, 1965) n. comb., and *H. acronea* (Coetzee, 1956) Sledge & Golden, 1964 is returned to *M. acronea* Coetzee, 1956.

8.25 WHITEHEAD, A. G. & TITE, D. J. (1967) Small doses of "D-D" soil fumigant to control free-living nematodes injurious to sugar beet. *Pl. Path.* **16**, 107–109.

Small doses of "D-D" kill many free-living nematodes in sandy soil and can significantly increase yields of sugar beet and barley. The fumigant can be placed during ploughing and its position indicated by drilling rows of winter wheat at intervals on the ploughed land. The rows of wheat act as markers in the spring and allow spring-sown crops to be drilled in the fumigated bands of soil.

Insecticides and Fungicides Department

GENERAL PAPERS

9.1 ELLIOTT, M. (1967) Synthesizing pyrethrin-like insecticides. *Science Journal* (March), 3–8.

9.2 LORD, K. A. (1966) Insecticides and Fungicides Department, Rothamsted Experimental Station, Harpenden. *Wld Rev. Pest Control* **5**, 176–186.

9.3 NEEDHAM, P. H. & STEVENSON, J. H. (1967) Bee poisoning in 1966. *Bee Wld* **48** (1), 7.

9.4 SAWICKI, R. M. & FARNHAM, A. W. (1967) The use of visible mutant markers in the study of resistance of house flies to insecticides. *Proceedings of the 4th British Insecticide and Fungicide Conference* 1967, 355–363.

RESEARCH PAPERS

9.5 BANKS, C. J. & MACAULAY, E. D. M. (1967) Effects of *Aphis fabae* Scop. and of its attendant ants and insect predators on yields of field beans (*Vicia faba* L.). *Ann. appl. Biol.* **60**, 445–453.
(For Summary see No. 10.9)

9.6 BASHEIR, S. EL (1967) Causes of resistance to DDT in a diazinon-selected and a DDT-selected strain of house-flies. *Ent. exp. & appl.* **10**, 111–126.

The causes of resistance to DDT in a DDT-selected (F58W) and a diazinon-selected (SKA) strain of house-flies differed.

Small (1 μg DDT/fly) topically applied doses penetrated more slowly into the SKA than into the F58W or susceptible strains. Large doses (32 μg/fly) penetrated equally fast into all strains.

The two resistant strains metabolised DDT rapidly and the susceptible strain slowly. The only metabolite identified was DDE.

WARF anti-resistant is a powerful synergist for DDT in the F58W strain, and prevents the formation of DDE. WARF anti-resistant is a less good synergist in the SKA strain, which possesses other mechanisms for metabolising DDT and also DDE.

DDT or its decomposition products seem to interact strongly with the tissues of SKA flies from which they are not readily extracted.

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9.7 ELLIOTT, M., FARNHAM, A. W., JANES, N. F., NEEDHAM, P. H. & PEARSON, B. C. (1967) 5-Benzyl-3-furylmethyl chrysanthemate: a new potent insecticide. *Nature, Lond.* **213**, 493–494.

5-Benzyl-3-furylmethyl (+)-*trans*-chrysanthemate (I), is 55 times as toxic to adult female *Musca domestica* L. (house-flies) as the mixed esters of the natural pyrethrins, nearly three times as toxic as parathion and more than five times as toxic as diazinon, and 10 times as toxic as the natural pyrethrins and 13 times as toxic as parathion to adult *Phaedon cochleariae* Fab. (mustard beetles). This insecticidal activity is greater than has been found before in a compound containing only carbon, hydrogen and oxygen.

Details of this and related compounds, and of the methods of synthesis, are discussed.

9.8 ELLIOTT, M., JANES, N. F. & JEFFS, K. A. (1967) 2,4-Dimethylphenylacetic acid from cyanodihydrocarvone. *Chemy. Ind.*, 1175.

2,4-Dimethylphenylacetic acid, not 2,3,6-trimethylbenzoic acid, is obtained when the lactam from treating cyanodihydrocarvone with amyl nitrite is heated with hydrochloric acid.

9.9 ELLIOTT, M. & JANES, N. F. (1967) Synthesis of 4-Allyl- and 4-Benzyl-2,6-dimethylbromobenzene from 2,6-Xylidine. *J. Chem. Soc.* (C), 1780–1782.

N-Allyl-2,6-xylidine was unchanged when heated alone, but rearranged to 4-allyl-2,6-xylidine with zinc chloride in refluxing xylene. When the hydrochloride was heated alone the principal reaction was dissociation to allyl chloride and xylidine, and only a trace of 4-allyl compound was formed. In contrast, *N*-benzyl-2,6-xylidine did not rearrange in the presence of zinc chloride, but the required 4-benzyl-2,6-xylidine was obtained by direct benzylation of 2,6-xylidine. The 4-allyl- and 4-benzyl-2,6-xylidines were converted smoothly to the corresponding bromobenzenes by the Sandmeyer reaction.

9.10 ELLIOTT, M., JANES, N. F. & PEARSON, B. C. (1967) The pyrethrins and related compounds. IX. Alkenylbenzyl and benzylbenzyl chrysanthemates. *J. Sci. Fd Agric.* **18**, 325–331.

The syntheses of 4-allylbenzyl, 4-benzylbenzyl and other related benzyl chrysanthemates are described. The benzyl alcohols were made by reduction of benzoic esters when these were readily obtainable; otherwise they were made either by Grignard reactions of appropriately substituted bromobenzenes with formaldehyde, or by reactions of alkenyl halides with Grignard derivatives of bromobenzyl alcohols in which the hydroxyl group was protected as its tetrahydropyranyl ether.

9.11 ELLIOTT, M., FARNHAM, A. W., JANES, N. F., NEEDHAM, P. H., PEARSON, B. C. & STEVENSON, J. H. (1967) New synthetic insecticidal compounds related to the pyrethrins. *Proceedings of the 4th British Insecticide and Fungicide Conference* 1967, 437–443.

In the most potent insecticidal esters of chrysanthemic acid the alcoholic component has a side chain with an activated methylene group held by a planar ring in a definite stereochemical relation to the acid part of the molecule.

Of the compounds that fulfil this condition, the most toxic have spatial arrangements very similar to those in the natural pyrethrins. This situation is found in 5-benzyl-3-furylmethyl (+)-*trans*-chrysanthemate, the best synthetic compound so far.

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The toxicity and susceptibility to synergism of this compound and others related to it are compared with those of other pyrethroids and of insecticides of other classes.

9.12 ELLIOTT, M., HARPER, S. H. & KAZI, M. A. (1967) Experiments on the synthesis of the pyrethrins. XIV. Rethrins and the cyclopentadienone related to 3-methylcyclopent-2-enone. *J. Sci. Fd Agric.* **18**, 167–171.

Dimeric 3-methylcyclopentadienone was obtained by dehydrobromination of 4-bromo-3-methylcyclopentenone and by hydrolysis of 4-hydroxy-3-methylcyclopentenone formate. Four structures for the dimer were possible. Synthesis and spectroscopic evidence showed that the dimer obtained was formed by addition to the unsubstituted double bond, with the methyl group on the norbornene ring in the position more remote from the carbonyl group of the cyclopentenone. Decarbonmonoxylation of the dimer gave 3,5-dimethylindanone, synthesised for comparison by another route.

Contrary to an earlier report, pyrolysis of 9,10 dihydro-9,10-(4,5-3-methylcyclopent-2-enono)anthracene (obtained by alkaline cyclisation of the adduct of anthracene and diacetyl ethylene) gave mainly 3,5-dimethylindanone and not 3-methylcyclopentadienone.

Rethrins with no side chain in the alcoholic part of the molecule were synthesised from 4-bromo-3-methylcyclopent-2-enone. Allethrolone cyclopropane carboxylate was made to compare its insecticidal activity with allethrolone chrysanthemate.

9.13 FREE, J. B., NEEDHAM, P. H., RACEY, P. A. & STEVENSON, J. H. (1967) The effect on honeybee mortality of applying insecticides as sprays or granules to flowering field beans. *J. Sci. Fd Agric.* **18**, 133–138.
(For summary see No. 11.12)

9.14 GRAHAM-BRYCE, I. J. (1967) Method of supplying water to soil at osmotically controlled potentials. *Chemy Ind.* 353–354.

When soil is separated from a suitable osmotic solution by a semi-permeable membrane water will move from solution to soil only when the tension in the soil exceeds that in the osmotic solution. This principle is used to control the potential at which water enters soil in pot experiments. Pots are made from Visking dialysis tubing supported inside perforated polythene pipe. After packing with soil at a suitable moisture content, the pots are placed in tanks of polyethylene glycol (PEG) solution which are maintained at constant concentration so that water can be supplied to the soil continuously and automatically at known potentials. A simple isopiestic method for determining the osmotic pressure of the PEG solutions is described. Moisture control was followed in pots containing soil only and others planted with wheat. After an initial period of adjustment the weights of pots remained almost constant for periods of up to 4 weeks. Longer periods could not be studied because the membrane decomposes. At the end of experiments examination of the soils showed that below a drier surface layer water content varied little throughout the soil except for a small tendency for the soil to become wetter from top to bottom of the pots.

9.15 GRAHAM-BRYCE, I. J. (1967) Adsorption of disulfoton by soil. *J. Sci. Fd Agric.* **18**, 72–77.

Adsorption of the systemic insecticide disulfoton (diethyl S-[2-(ethylthio)-ethyl]phosphorothiolothionate) by soil was studied using a wet-slurry technique. Extraction of soils and solutions after equilibration showed that more disulfoton was lost from solution than could be extracted from soil, principally

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because of microbial alteration and adsorption by glass. In two contrasting soils equilibration was complete by 3 hours and air-dry soils in the laboratory adsorbed similarly to the moist field soils from which they were derived. Adsorption was fully reversible if desorption took place immediately after uptake when soils were still wet, but the release was modified when the soils were allowed to dry thoroughly between adsorption and desorption. The empirical Freundlich isotherm fitted adsorption results for 17 different soils well. The isotherms had different curvatures, but deviations from linearity were small, so that linear isotherms provide good approximations. Comparison of the slopes of the best-fitting linear relationships showed that adsorption was closely related to the amount of organic matter in the soil.

9.16 GRAHAM-BRYCE, I. J. & ETHERIDGE, P. (1967) Effect of soil moisture conditions on uptake of systemic insecticides from soil by plants. *Proceedings of the 4th British Insecticide and Fungicide Conference* 1967, 336–343.

The influence of soil-moisture conditions on the effectiveness of the soil-applied systemic insecticides disulfoton, phorate, dimethoate and menazon against aphids was studied by experiments with wheat in pots and by irrigating potatoes in the field. Soil moisture was controlled in the pots osmotically. Results are interpreted in relation to other experiments on adsorption and diffusion in soil. In the pots effects of moisture were small, but effectiveness of dimethoate usually decreased and that of disulfoton increased with increasing moisture. Uptake by the wheat was probably not limited by movement to the roots, but by adsorption by the roots, which depends on the concentration in the soil solution. In the field irrigation increased effectiveness of dimethoate and menazon, but not disulfoton and phorate. This is not simply because of different relationships between moisture content and diffusion rates for these insecticides in soil resulting from different physical properties as was previously suggested. Other possible explanations are considered.

9.17 GRIFFITHS, D. C. (1967) The effects of insecticides on the biting behaviour of wireworms (*Agriotes* spp.). *Ent. exp. appl.* **10**, 171–180.

Filter-paper discs soaked in nutrient were used to study how insecticides affect the biting behaviour of wireworms. When wireworms were buried in soils treated with 3·7 ppm aldrin, Bayer 38156, N 2790 or thionazin they stopped biting several days or weeks before they died. Three out of 10 wireworms slowly recovered their biting ability after being buried for 4 days in soil containing 3·7 ppm γ-BHC. Biting behaviour was little affected when wireworms were confined to soils containing insecticides known to be not very toxic to wireworms.

Nutrient discs treated with thionazin or γ-BHC were bitten less often than discs containing nutrient alone. Those treated with nutrient and aldrin were bitten almost as often as nutrient discs, but the wireworms later stopped biting and died.

9.18 GRIFFITHS, D. C. & SCOTT, G. C. (1967) Persistence and effectiveness of carbophenothion, chlorfenvinphos and ethion seed dressings to control wheat-bulb fly, *Leptohylemyia coarctata*. *Proceedings of the 4th British Insecticide and Fungicide Conference* 1967, 118–123.

Cappelle winter wheat seeds dressed with carbophenothion, chlorfenvinphos, ethion or fungicide alone (controls) were sown on a wheat-bulb-fly-infested site in October, November and December. Plant samples were taken in February for

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extraction and estimation of insecticide, and in March for recording the biological effects of the treatments. The amounts of insecticide recovered from the seeds and roots of February samples were similar for all three sowings and were about 30% of the carbophenothion, 2% of the chlorfenvinphos and 15% of the ethion that had been applied to the seeds. Little insecticide was found inside the "bulbs" of the plants. The biological effects of the treatments were greatest with the late sowings, where the controls had twice as many damaged shoots and only half as many healthy shoots as treated plants. Yields were taken only from the early sown plots, where the differences were least, and although all three treatments yielded more than the controls, the increases were not significant.

9.19 GRIFFITHS, D. C., RAW, F. & LOFTY, J. R. (1967) The effects on soil fauna of insecticides tested against wireworms (*Agriotes* spp.) in wheat. *Ann. appl. Biol.* **60**, 479–490.

The organophosphorus insecticides Bayer 38156 (*O*-ethyl *S*-*p*-tolyl ethyl phosphonodithioate), trichloronate, Stauffer N 2790 (*O*-ethyl *S*-phenyl phosphonodithioate), thionazin and fenitrothion were compared with aldrin, dieldrin and γ-BHC for their effects on soil fauna, particularly wireworms, and on crop yields in 1964 and 1965. At 1·5 lb active ingredient/acre none of the organophosphates had as great an effect on wireworms as an aldrin spray at 2·25 lb a.i./acre or a dieldrin seed dressing at 2·25 lb a.i./acre. Some treatments significantly increased and some significantly decreased numbers of mites and Collembola. Except for *Allolobophora chlorotica* in plots treated with Bayer 38156, earthworm numbers were greater in plots sprayed with Bayer 38156 or aldrin, or sown with dieldrin-dressed seeds, than in untreated plots. In May 1964, 1 month after sowing, untreated plots had significantly fewer plants than plots sprayed with aldrin, trichloronate or Bayer 38156, or sown with γ-BHC or dieldrin-dressed seeds, but yields from untreated plots at harvest were large for such a wireworm population and did not differ significantly from yields of treated plots in either year.

The persistence of thionazin and Bayer 38156 in treated plots was measured by a bioassay using Collembola. Bayer 38156 was detected in plots 1 month after spraying, but not after 6 months. Thionazin left detectable residues 1 month after spraying in the two acid plots, but not in the two alkaline plots. More frequent samples taken from thionazin-treated plots in 1965 showed a similar pattern of persistence, and laboratory tests, using soil mixed with various amounts of powdered calcium carbonate, confirmed that thionazin persisted longer in more acid soils.

9.20 GRIFFITHS, D. C., SCOTT, G. C., MASKELL, F. E. & MATHIAS, P. L. (1967) The control of wheat-bulb fly (*Leptohylemyia coarctata* Fall.) in winter wheat. Single row trials of experimental seed dressings. *Pl. Path.* **16** (1), Suppl. 11–13.

Experimental materials were tested against wheat-bulb fly in 1964/65 and 1965/66 by formulating them as seed-dressings, sticking the insecticidal dressing and organomercury fungicide to the seeds with methyl cellulose and sowing the seeds in infested fields as 10-ft rows replicated four times. Seeds dressed with heptachlor, as a standard, and with fungicide alone, as a control, were included for comparison.

Of the twelve experimental compounds tested on a peaty loam site in 1964/65, ethion gave the best results. Plants grown from seeds dressed with 0·15% a.i. ethion had only 9% damaged shoots compared with 38% damaged shoots in the controls. In 1965/66 11 more materials were tested at two sites, a peaty loam and

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a clay loam. Ethion again did well, and one other organophosphorus insecticide, carbophenothion, was about equally effective.

9.21 GWIAZDA, M. & LORD, K. A. (1967) Factors affecting the toxicity of diazinon to *Musca domestica* L. *Ann. appl. Biol.* **59**, 221–232.

Processes affecting the toxicity of diazinon to a susceptible and a resistant strain of house-flies were examined.

More evidence was obtained to show that slower penetration of diazinon through the integument of resistant flies is a cause of resistance.

Small amounts of two decomposition products were found in both strains. The decomposition mechanisms in these strains were differently distributed and, although detoxication of diazinon in the two strains is quantitatively similar and small, it may contribute to resistance.

Traces of diazoxon were detected when diazinon was incubated with tissue extracts of either strain.

Tissue extracts of resistant, but not of susceptible, flies decomposed significant amounts of diazinon in 1 hour, and the ability to decompose diazoxon seems to be an important cause of resistance.

Tissues of both strains sorbed diazinon from aqueous solution similarly; the quantities sorbed were large and suggest that sorption may increase the amount of poison needed inside the insects to kill, by between 5 and 40 times.

9.22 KING, H. G. C., PRUDEN, G. & JANES, N. F. (1967) Synthesis of the active components of commercial Titan yellow for use in the determination of magnesium. *Analyst, Lond.* **92**, 695.
(For summary see No. 3.6)

9.23 LORD, K. A., GREGORY, G. E. & BURT, P. E. (1967) The penetration of acetylcholine into the central nervous system of the cockroach *Periplaneta americana* L. *J. exp. Biol.* **46**, 153–159.

The hydrolysis of acetylcholine and acetylthiocholine by cockroach ventral nerve cords was examined by biochemical and histochemical methods, and used as an indication of the penetration of the substrates into the nerve cord. The rate of penetration of acetylcholine into intact nerve cords, measured biochemically, agrees well with estimates by previous workers using a more direct method. A barrier to the penetration of the two cholinesterase substrates is destroyed by treatment with acetone, which increased the rate of hydrolysis of acetylcholine five to tenfold. Histochemical tests showed that acetylthiocholine is probably prevented from penetrating freely to the neuropile of the ganglia by the glial cell layer. When the restriction is abolished by treating the cord with acetone, acetylthiocholine reaches the neuropile but penetrates it for only a short distance, probably because it is decomposed by the cholinesterase in this region.

9.24 LORD, K. A., SCOTT, G. C., JEFFS, K. A., GRIFFITHS, D. C. & MASKELL, F. E. (1967) Persistence and distribution of insecticidal seed-dressings for control of wheat-bulb fly. *Ann. appl. Biol.* **60**, 173–180.

Samples of plants and soil from two experimental sites, one clay loam and one peaty loam, were analysed chemically to try to explain differing results with γ-BHC and dieldrin seed-dressings applied to control wheat-bulb fly on different soil types, and to suggest reasons for patchy plant stands and occasional failure to control the pest. Seed dressed with dieldrin yielded more than untreated seed on both sites, whereas seed treated with γ-BHC yielded as much as seed treated with dieldrin on the clay site, but it yielded less than untreated seed on peat. The chemical analyses showed that the poor performance of γ-BHC on

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the peat site could not be explained by its failure to persist, because the soil still contained considerable quantities of γ-BHC at the time of insect attack. Possible reasons may be sorption of the poison by organic matter making it less available, and deeper sowing, permitting larvae to reach the plants without prolonged contact with the insecticide.

Bayer 38156 (*O*-ethyl *S*-*p*-tolyl ethyl phosphonodithioate) and trichloronate (*O*-ethyl O-2,4,5-trichlorophenyl ethyl phosphonothionate) persisted in soil long enough and were sufficiently toxic to wheat-bulb fly to suggest that organophosphorus compounds might provide alternatives to chlorinated hydrocarbon insecticides for control of the fly.

Analyses made on seeds dressed at the laboratory for the experiment showed that the amounts of insecticide on seeds were smaller than expected and that the amounts on individual seeds differed greatly. Of 10 samples of seeds dressed commercially with γ-BHC, three carried very little insecticide, and the variations in the other seven samples were greater than with experimentally applied dressings.

9.25 McIntosh, A. H. & Eveling, D. W. (1967) Effect of wax and lanolin emulsions on the efficiency of potato blight fungicides in laboratory tests. *Ann. appl. Biol.* **60**, 223–230.

Four potato-blight fungicides (copper oxychloride, tetrachloroisophthalonitrile, zineb and fentin acetate) were formulated either by adding emulsions of paraffin wax or lanolin to solid fungicide dispersed in water, or by dissolving the fungicide in wax or lanolin and then emulsifying the solution; all emulsions were non-creaming and extremely stable. These formulations were compared in the laboratory with commercial wettable powders of the same fungicides for their ability to protect detached potato leaflets against infection by *Phytophthora infestans* (Mont.) de Bary; in these and in other laboratory tests the quality of rainfastness, or tenacity, was involved directly or indirectly.

Most of the wax or lanolin formulations gave better protection than the wettable powders. It is suggested that the wax and lanolin acted as viscous stickers, suitably increasing the rainfastness of deposits on leaflets; and that when the fungicide was dissolved in the wax or lanolin before emulsification the particle size of the dispersed fungicide was extremely small, a quality that increases biological action.

9.26 Raw, F., Lofty, J. R. & Potter, C. (1968) Studies in the chemical control of wireworms (*Agriotes* spp.). 3. The direct and residual effects of BHC, aldrin and dieldrin. *Bull. ent. Res.* (In the press.)
(For summary see No. 10.22)

9.27 Sawicki, R. M. & Farnham, A. W. (1967) Genetics of resistance to insecticides of the SKA strain of *Musca domestica* L. I. Location of the main factors responsible for the maintenance of high DDT-resistance in diazinon-selected SKA flies. *Ent. exp. appl.* **10**, 253–262.

The factors responsible for resistance to diazinon and DDT in diazinon-selected SKA flies are either linked or common to both insecticides. This is why SKA flies are very resistant to DDT, although they have been selected solely with diazinon for over 9 years. DDT-ase (DDT-dehydrochlorinase), which is inhibited by FDMC (bis-(*p*-chlorophenyl)-trifluoromethyl carbinol) and by WARF-antiresistant (N,N-di-*n*-butyl-*p*-chlorobenzene sulphonamide), and little aliesterase are on the V linkage group (Hiroyoshi's numbering system). A resistance factor (R3) inhibited by sesamex (2-(3,4 methylene dioxyphenoxy)

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3,6,9-trioxaundecane) most probably common to DDT and diazinon is on the III linkage group. The third factor is recessive, segregates independently of the other factors and is unaffected by the synergists. It probably confers only moderate resistance to DDT. This factor seems to segregate together with a factor conferring weak resistance to diazinon. DDT-ase occurs in fewer than 20% of the SKA flies. R3 seems to be the major factor of resistance to DDT in SKA flies. When heterozygous R3 gives only moderate resistance to DDT.

9.28 SAWICKI, R. M., (FRANCO, M. G. & MILANI, R.) (1966) Genetic analysis of non-recessive factors of resistance to diazinon in the SKA strain of the housefly (*Musca domestica* L.). *Wld Hlth Bull.* **35**, 893–903.

The recent allocation of many visible mutants to specific linkage-groups has made possible their use as genetic markers in the study of the inheritance of insecticide resistance. In most organophosphorus-resistant strains resistance is controlled by a single gene on the V linkage-group responsible for resistance and small aliesterase activity, but in some strains more than one factor is present. The present work was done to analyse the genetics of resistance to diazinon in a strain (the SKA strain) bred from two diazinon-resistant strains. Crosses between the SKA flies and four susceptible recessive marker strains, each marked on one linkage-group, followed by test-crosses with recessive markers and by bioassays of each cross, have shown that non-recessive factors for resistance to diazinon are present on the IV and V linkage-groups. The SKA strain genetically resembles its parents, but differs by being considerably more resistant.

9.29 WAY, M. J. (1966) The nature and causes of annual fluctuations in numbers of *Aphis fabae* Scop. on field beans (*Vicia faba*). *Ann. appl. Biol.* **59**, 175–188.

Experiments for nine successive years showed that *Aphis fabae* Scop. populations on mid-March-sown field beans were either large with peak densities between late June and mid-July or very small with peak densities in early August. It is concluded that the largest populations develop when many plants have been colonised by primary migrants from *Euonymus europaeus* and temperature and radiations are above average during June and early July, as in the year 1957. Cold, dull weather slows multiplication and decreases the size of the peak population even when there is a large initial colonisation, as in 1954. The peak population may also be less than predicted from the initial colonisation when natural enemies are exceptionally abundant in early June, as in the year 1960. Yield losses of mid-March-sown crops in years of large *A. fabae* populations ranged from 53% in 1954 (peak population of 1260 aphids per plant) to 100% in 1957 (6920 aphids per plant).

Small summer populations with peak densities of about 0·2–85 aphids per plant developed on mid-March-sown plots in years when fewer than about 6% of the plants were colonised by primary migrants. Yield losses ranged from 6·3 to 13·6%.

Three years' experiments indicated that crops sown in late April or May are relatively lightly infested in years when large populations develop on mid-March-sown crops. Conversely, they may be relatively heavily infested when the populations on these crops are small, as in 1955, when temperatures and sunshine during July and early August were above average.

Small and large early summer populations tend to alternate in successive years. The alternation is upset by hot, sunny weather during July and August, and perhaps September and October, which compresses the population cycle. Thus the large and small populations expected from this alternation in 1956 and

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1960 developed instead during exceptionally fine weather in late summer 1955 and 1959, converting 1956 and 1960 to years of small and large populations respectively.

9.30 WAY, M. J. & BANKS, C. J. (1967) Intra-specific mechanisms in relation to the natural regulation of numbers of *Aphis fabae* Scop. *Ann. appl. Biol.* **59**, 189–205.

Parthenogenetic virginoparous apterae of *Aphis fabae* Scop. on field beans (*Vicia faba*) reproduced faster initially in populations of eight colonising apterae than in those with 2–4 or 16–32 per plant. The aphids were at first mutually benefited but were quickly affected by competition as numbers rose above the critical density represented by about eight apterae and their first progeny. This is because the aphids remained densely aggregated and seemingly created a local shortage despite abundant food and space elsewhere on the plant. Such self-induced competition provides the basis for self-regulation of numbers of *A. fabae* in relation to: (1) food and space provided by the growing plant, and (2) mortality from natural enemies and from other causes including insecticides.

As competition increased, the multiplication of *A. fabae* populations slowed, newly formed adult apterae emigrated and increasing numbers of alatae were formed. The mean weights of apterae decreased from about 1·8–0·3 mg and of alatae from 0·9 to 0·2 mg. Such decrease probably favours production of many adults that might otherwise fail to mature.

Experiments in a glasshouse and in field cages indicated the success with which an *A. fabae* population adapts to and exploits a growing plant. Field-bean plants sown in mid-March and infested as in the field produced an average of 15 000–17 000 *A. fabae* emigrants per plant, of which 78–84% were adults (mostly alatae). This is equivalent to about 1600 million alate emigrants from 1 acre (0·4 hectare) of an infested field-bean crop.

Entomology Department

THESES

10.1 RYAN, M. F. (1967) Studies of the natural mortality of the wheat-bulb fly *Leptohylemyia coarctata* Fall. (Diptera: Anthomyiidae). Ph.D. Thesis, University of London.

10.2 YOUDEOWEI, A. (1967) Aggregation in *Dysdercus intermedius* Distant (Heteroptera: Pyrrhocoridae). Ph.D. Thesis, University of London.

GENERAL PAPERS

10.3 EDWARDS, C. A. (1967) The effects of herbicides on soil invertebrates. In: *Weed control handbook*. Ed. W. W. Fletcher, Oxford: Blackwells.

10.4 EDWARDS, C. A. (1967) Loss of aldrin and dieldrin residues from soils by leaching and ecological studies of their residues. *Proc. Symposium on the Science and Technology of Residual Insecticides in Food Production*, Washington. (In the press.)

10.5 EDWARDS, C. A. (1967) Pesticide residues in soils. *Proc. Southern Regional Pesticide-Chemical Application School, Wichita Falls, Texas*; pp. 52–59, 70–71.

10.6 JUDENKO, E. (1967) Methods for field trials to assess the loss of yield of crops attacked by pests. *F.A.O. Symposium on crop losses*. Rome, 1967, 75–78.

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10.7 RAW, F. (1967) Some aspects of the wheat-bulb fly problem (The 5th Barnes Memorial Lecture). *Ann. appl. Biol.* **59**, 155–173.

10.8 (STRICKLAND, A. H.) & BARDNER, R. (1967) A review of current methods applicable to measuring crop losses due to insects. *F.A.O. Symposium on crop losses*. Rome, 1967, 289–309.

RESEARCH PAPERS

10.9 BANKS, C. J. & MACAULAY, E. D. M. (1967) Effects of *Aphis fabae* Scop. and of its attendant ants and insect predators on yield of field beans (*Vicia faba* L.). *Ann. appl. Biol.* **60**, 445–453.

Predators (mainly coccinellid adults and larvae and syrphid larvae), although few, were important in decreasing numbers of *Aphis fabae* on a small plot of field beans during the early stages of infestation in a year favourable to aphid. At the same time ants (*Lasius niger* L.), attending aphids on other plants on the same plot, effectively protected the aphids from predators for about 2 weeks, enabling the attended aphids to multiply faster than the unattended. When all aphid populations started to decline predators became more numerous and accelerated the decline on both sets of plants.

Bean plants without aphids yielded 56 seeds per plant; those with aphids but free from ants gave 17; and those with ant-attended aphids, eight seeds per plant. The damage and loss of yield was caused by the large aphid populations that developed when the pods were maturing, and not by the fewer aphids present when the plants were in flower. It appears that small temporary infestations during flowering might increase the yield of field beans.

10.10 BARDNER, R. (1968) Wheat-Bulb Fly, *Leptohylemyia coarctata* Fall. and its effect on the growth and yield of wheat. *Ann. appl. Biol.* **61**. (In the press.)

With an infestation of between 1·1 and 1·7 million eggs/acre, typical of a moderate attack, larvae had little effect on the yield of wheat sown in late October, as the plants had two shoots each when first attacked, and few plants were killed. On plots sown later, yield was lessened by up to 22%, as plants had only a single shoot when larvae first entered them, and many plants were killed.

The main effect of wheat-bulb fly was to make ear-bearing shoots fewer. Surviving plants partially compensated for the death of others by producing more ear-bearing shoots with heavier ears and slightly heavier seeds than plants in an unattacked crop.

Damage was not evenly distributed through the crop, and killed plants often occurred in patches several feet across. Competition between surviving plants may have restricted the amount of compensatory growth. Wheat on the attacked plots ripened more slowly and unevenly than on the unattacked plots.

The number of shoots that survive attack depends partly on the weather, which affects the growth of the plants and activity of the larvae. Forecasting the effect of an attack is difficult, but because of compensatory growth the % loss of yield will probably be less than the % of plants infested by newly hatched larvae.

10.11 COSTA, C. L. & LEWIS, T. (1968) The relationship between the size of yellow water traps and catches of aphids. *Ent. exp. & appl.* (In the press.)

The trapping efficiency per unit area of rectangular yellow water traps decreased the larger the trap. The relationship between numbers caught and the

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size of trap is linear when plotted on a square-root scale. Species are attracted differently to traps of different size, so traps of a standard size, and preferably circular, are recommended for comparing the aerial population at different places and times.

10.12 EDWARDS, C. A. (1968) The effects of gamma irradiation on populations of soil invertebrates. *Proc. 2nd Symp. Radioecology*. (In the press.)

Invertebrate animals living in soil or on moist plaster of Paris were irradiated with gamma-rays from a cobalt source. Soil samples and cultures were adequately replicated, and radiation doses ranged from 10 K.rads through 25, 50, 100 and 200 K.rads. The animals in culture included representative Oligochaeta, "Myriapoda", Acarina, Collembola and Insecta. Susceptibility to radiation differed greatly both between and within groups. Oribatid mites were most resistant, surviving up to 50 days after exposure to 200 K.rads. Isopods, which were most susceptible, were all dead 60 days after exposure to 10 K.rads. Active animals were usually more susceptible than sluggish ones.

Mortality–time curves were not linear even on a probit scale, but were usually distinguishable into an initial steep part and a shallow subsequent one. Percentage mortalities were positively correlated with radiation dosages, but not in a simple linear manner.

Populations of all main groups of soil invertebrates were estimated regularly for 3 months after irradiation. Most species decreased in numbers, but a few multiplied after a small dose of radiation, probably because predators were killed before their prey. Animals in cultures were usually more susceptible to irradiation than those in soil.

10.13 EDWARDS, C. A., THOMPSON, A. R. & (BEYNON, K. I.) (1968) Some effects of chlorfenvinphos, an organophosphorus insecticide, on populations of soil animals. *Revue Ecol. & Biol. Sol.* (In the press.)

Studies were made on the effects on soil invertebrates of the organophosphorus insecticide chlorfenvinphos ("Birlane", diethyl 1-(2′,4′-dichlorophenyl)-2-chlorovinyl phosphate, previously known as compound SD 7859 and GC 4072). The insecticide, which increased the numbers of Collembola and sometimes Oribatidae and decreased the numbers of Mesostigmata, controls Diptera well, but numbers of Coleoptera (mostly wireworms, chafers and weevils) were never decreased by more than 70%. After an initial kill the numbers of dipterous larvae increased in the soil as the amount of insecticide gradually diminished. Chlorfenvinphos has little effect on Symphyla and Diplopoda.

From a fifth to a half of the earthworms in the field were killed, and more surface-dwelling forms were killed than worms in deeper layers. Even after 21 weeks in soil treated with 6 ppm of chlorfenvinphos, earthworms contained no more than 0·02 ppm of the insecticide and its metabolites. Other groups of invertebrates were not drastically affected.

Effects of chlorfenvinphos on soil fauna seem unlikely to persist for more than one year.

10.14 EDWARDS, C. A., THOMPSON, A. R. & LOFTY, J. R. (1968) Changes in soil invertebrate populations caused by some organophosphorus insecticides. *Proceedings of the 4th British Insecticide and Fungicide Conference* 1967.

Results are given of the effect of the organophosphorus insecticides parathion, diazinon, phorate and disulfoton on soil invertebrates. Numbers of the animals and the biomass were decreased less than by aldrin and dieldrin. Numbers of

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parasitic mites were greatly lessened, but, as in response to treatment by DDT, springtails, trombidiform and oribatid mites often increased. Effects on these groups often persisted longer than the residues of the insecticides. Only phorate lessened numbers of earthworms significantly. All four lessened numbers of pauropods. Beetles were affected only by parathion. No insecticide controlled symphylids economically.

10.15 EDWARDS, C. A. & (BELFIELD, W.) (1967) A new genus and species of Symphyla, *Neosymphyla ghanensis* with comments on *Symphyla segmentatia*. *Revue Ecol. & Biol. Sol.* **4**, 517–521.

A new genus of Symphyla, *Neosymphyla ghanensis*, is described. It is distinctive in having 14 scuta with posterior projections, whereas all other genera have 13. It is very small and dwells mainly in topsoil.

10.16 FRENCH, R. A. (1968) Migration Records 1965. *Entomologist* **101**. (In the press.)

10.17 FRENCH, R. A. (1968) *Laphygma exigua* Hübner (Lepidoptera: Noctuidae) in the British Isles with particular reference to 1962. *J. Anim. Ecol.* (In the press.)

The appearance of *Laphygma exigua* in the British Isles, particularly in the years 1947–66, can be shown to be correlated with a wind system able to transport the moths from a known source area to the south into the British Isles. The typical conditions for such a dispersal are discussed. The time of arrival seems to depend on which of two major source areas produce enough moths coincident with a wind able to carry them to the British Isles.

10.18 GERARD, B. M. (1967) Factors affecting earthworms in pastures. *J. Anim. Ecol.* **36**, 235–252.

This paper deals with the seasonal effects of temperature and water on the depth and activity of six species of earthworms in pasture-land, with the life history of two of them and with the reactions of these species in different water regimes. The adults, juveniles and cocoons were identified using descriptions given by Gerard (1964).

10.19 JONES, MARGARET G. (1967) Observations on the two races of the groundnut aphid, *Aphis craccivora* Koch. *Ent. exp. & appl.* **10**, 31–38.

Two clones of *Aphis craccivora*, one from Nigeria and one from Kenya, differed in their ability to transmit the $GRVW_1$ strain of the groundnut rosette virus (OKUSANYA, 1965). Comparison of body measurements of the two clones showed them to be two distinct but overlapping populations. The Nigerian clone formed colonies on *Onobrychus viciifolia*, *Gomphrena globosa* and young *Soya max* more readily than the Kenya clone. The fecundity of single viviparous females of the two clones on groundnut and bean does not differ significantly. Alatae produce half as many young as apterae.

10.20 JUDENKO, E. (1967) The loss of yield in a crop of sweet corn (*Zea mays* L.) following the complete destruction of some plants at an early stage by brown rats (*Rattus norvegicus* Berk.). *PANS.* Sect. A. **13**, 412–414.

Yield was assessed as total green weight, total weight of all cobs, number of marketable cobs and current value of marketable cobs. Compensatory activity of the crop after attack by rats was assessed. Yield without rat attack was esti-

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mated by multiplying the expected mean yield of undamaged plants by the total number of plants (both damaged and undamaged), and the losses were estimated by subtracting the actual yield obtained at harvest from this figure.

10.21 LEWIS, T. (1967) The horizontal and vertical distribution of flying insects near artificial windbreaks. *Ann. appl. Biol.* **60**, 23–31.

Lath fences 3 ft and 8 ft high affected the horizontal distribution of flying insects similarly; most insects accumulated at 2–3 times the height of each fence to leeward, where catches, measured at 14 and 38 in. (0·4 times the height of the fence above the ground) were 30–40% greater than in exposed positions. Behind an 8-ft fence accumulations extended vertically to 12–16 ft (1·5–2·0 times the height of the fence). Vertical profiles of weak-flying insects, in winds >3 mph, differed in sheltered and exposed positions; in shelter the boundary layer was deeper and insects were more abundant nearer the ground than elsewhere. For strong flyers, and insects that flew only in winds <2 mph, vertical profiles in sheltered and exposed positions were indistinguishable.

10.22 RAW, F., LOFTY, J. R. & POTTER, C. (1968) Studies in the chemical control of wireworms (*Agriotes* spp.). 3. The direct and residual effects of BHC, aldrin and dieldrin. *Bull. ent. Res.* (In the press.)

Aldrin, dieldrin and BHC seed-dressings, aldrin spray and BHC dust combine-drilled with the seed, were tested for direct and residual effects on wireworms in winter and spring wheat.

In spring wheat BHC and dieldrin decreased numbers of wireworms and increased yield. Aldrin seed-dressing had no direct or residual effect. In winter wheat a dieldrin seed-dressing and BHC seed-dressing decreased wireworm populations as much as aldrin spray and BHC dust. The BHC seed-dressing also increased crop yield.

10.23 RAW, F., JONES, M. G. & GREGORY, P. H. (1968) The food of female wheat-bulb flies (*Leptohylemyia coarctata* (Fall.)) *Pl. Path.* **17**, 23–25.

In several areas of England female wheat-bulb flies feed chiefly on the conispores of *Septomyxa affinis* (Sherb.), a hyphomycete growing on dead wheat leaves and dead *Poa annua* at or just above the soil surface. The spores may supply the protein needed for the maturation of the eggs.

10.24 YOUDEOWEI, A. (1968) The behaviour of a cotton stainer *Dysdercus intermedius* Dist. (Heteroptera, Pyrrhocoridae) in a temperature gradient and the effect of temperature on aggregation. *Ent. exp. & appl.* (In the press.)

Problems relating to the distribution of insects in artificial temperature gradients are discussed and the meanings of terms defined. The distribution of insects in a temperature gradient can be expressed as the mean of the preferred range of positions taken and as the standard deviation about this mean.

Experiments with *Dysdercus intermedius* showed that, with 10 individuals in the gradient apparatus, distributions were unimodal, but with more insects than 10 distributions were bimodal with one peak in the "preferred temperature" range and another at the cold end of the apparatus.

When there was no gradient of temperature aggregations formed at temperatures below 30° C, but above 30° C insects began to scatter and at 43° C they did not aggregate.

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10.25 YOUDEOWEI, A. & CALAM, D. H. (1968) The morphology of the scent glands of *Dysdercus intermedius* Dist. (Pyrrhocoridae) and a preliminary analysis of the scent gland secretions of the fifth instar larvae. *Proc. R. Ent. Soc. Lond.* (In the press.)

All the larval stages of *D. intermedius* have three dorsal abdominal scent glands. They are simple sacs opening directly to the exterior. The first and second glands are small, colourless sacs, whereas the third is orange coloured and is about four times the size of each of the first two glands.

Bee Department

RESEARCH PAPERS

11.1 BAILEY, L. (1966) The effect of acid-hydrolysed sucrose on honeybees. *J. apicult. Res.* **5**, 127–136.

Sucrose or starch hydrolysed with mineral or organic acids is toxic for honeybees, whereas sucrose hydrolysed with invertase is not. The best-known products of the action of acids on hexoses, 5-hydroxymethylfuraldehyde (HMF), laevulinic acid and formic acid were similarly toxic to bees when fed to them, but only when more concentrated than in acid-hydrolysed sucrose. Neither the acids used to hydrolyse the carbohydrates nor the salts formed by neutralising them were toxic, so unknown products of acid hydrolysis must cause most of the harm to bees. Heated honey or old honey was less suitable for bees than fresh honey or sucrose; their suitability was inversely correlated with the concentration in them of HMF, but this was too small to cause the harm observed. Evidently substances that are more toxic than HMF must accumulate along with it in heated honey; these may be similar to those in acid-hydrolysed carbohydrates. Bees fed acid-hydrolysed carbohydrates developed "dysentery" before they died, possibly because essential solutes and water were lost from the tissue into the rectum, the contents of which were doubled, but only slightly diluted.

11.2 BAILEY, L. (1967) The effect of temperature on the pathogenicity of the fungus, *Ascosphaera apis*, for larvae of the honeybee, *Apis mellifera*. *Proceedings of the international Colloquium on Insect Pathology and Microbial Control, Wageningen* **1**, 162–167.

Honeybee larvae are most susceptible to infection by ingested spores of *Ascosphaera apis* when they are 3–4 days old and are chilled briefly 2 days later, immediately after they are sealed in their cells to pupate. Spores of *A. apis* germinate *in vitro* best when nearly anaerobic, but the mycelium is aerobic. Spores germinate *in vivo* in the larval gut, which is almost anaerobic. The mycelium survives in 3–4-day-old larvae better than in younger ones, probably because of the shorter time it is deprived of oxygen. It invades tissues of chilled larvae because chilling probably allows oxygen to reach and activate it; *in vitro* the fungus grows faster at usual brood temperatures (30–35° C) than when colder.

11.3 BAILEY, L. (1967) The incidence of *Acarapis woodi* in North American strains of honeybee in Britain. *J. apicult. Res.* **6**, 99–103.

Acarapis woodi was detectable in a larger percentage of colonies of "American" bees in Britain than of "British" bees in the same locality. Most infestation remained slight. British bees added to colonies of American bees became equally infested; so, individually, American bees are no more susceptible to infestation than British bees.

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11.4 BAILEY, L. (1967) The incidence of virus diseases in the honeybee. *Ann. appl. Biol.* **60**, 43–48.

Chronic bee-paralysis virus and sacbrood virus occur commonly in apparently normal honeybee colonies in Britain. Most sick adult bees not affected by *Nosema apis*, *Malpighamoeba mellificae* or *Acarapis woodi* have chronic paralysis, and most dead larvae not affected by micro-organisms have sacbrood. Both virus diseases are probably limited by hereditary factors, but unknown environmental factors also seem to influence disease. Paralysed bees from Australia, Canada, Eire, Germany and Mexico were found to be infected with chronic paralysis virus.

11.5 BUTLER, C. G. (1967) A sex attractant acting as an aphrodisiac in the honeybee (*Apis mellifera* L.). *Proc. R. ent. Soc. Lond.* (A) **42**, 71–76.

Drones trained to visit an area, by exposing 9-oxodecenoic acid there, closely examined freshly killed queens, queens that had been extracted in ethanol, wooden models of queens and worker bees, when these were suspended 8 m above the ground; but only very exceptionally did a drone mount a queen or worker unless her sting chamber was open. Evidence was obtained that the 9-oxodecenoic acid contained in the mandibular gland secretion on a queen's body acts as an aphrodisiac and stimulates a drone to mount her when her sting chamber is open.

11.6 BUTLER, C. G. & SIMPSON, J. (1967) Pheromones of the queen honeybee (*Apis mellifera* L.) which enable her workers to follow her when swarming. *Proc. R. ent. Soc. Lond.* (A) **42**, 149–154.

Flying bees from swarm clusters that had lost their queens were strongly attracted by the odour of 9-oxodecenoic acid, a pheromone produced in a queen's mandibular glands. However, they seldom clustered on cages containing this acid, and the bees that did so remained very restless. The odour of 9-hydroxydecenoic acid, which is also produced in a queen's mandibular glands, was also slightly attractive to flying bees seeking a queen; when they found a cage containing it they clustered quietly on it. The odour of a mixture of 9-oxodecenoic acid and 9-hydroxydecenoic acid attracted the flying bees and caused them to form large, quiet clusters on cages containing it. These two pheromones together were as attractive as the odours of live queens and seem responsible for enabling their workers to find them when swarming.

11.7 FREE, J. B. (1966) The foraging areas of honeybees in an orchard of standard apple trees. *J. appl. Ecol.* **3**, 261–268.

The number of honey and solitary bees visiting five apple varieties in an orchard were correlated with the abundance of their flowers. The relative attractiveness of each variety depended on the stage of flowering. Honeybees distinguished between at least some of the varieties and, when the variety being visited remained relatively attractive, tended to remain constant to it. When this variety became relatively less attractive they tended to move to another. The foraging areas of individual honeybees on attractive varieties remained quite small over consecutive trips. The implications of these results on the efficient planting of orchards for cross-pollination are discussed.

11.8 FREE, J. B. (1966) The pollination of the beans *Phaseolus multiflorus* and *Phaseolus vulgaris* by honeybees. *J. apicult. Res.* **5**, 87–91.

Runner-bean plants, isolated from insects, produced fewer pods and seeds than those visited by honeybees, but excluding bees made little difference to the yield of dwarf beans.

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11.9 FREE, J. B. (1967) Factors determining the collection of pollen by honeybee foragers. *Anim. Behav.* **15**, 134–144.

Individual bees quickly changed from collecting nectar to collecting pollen, and vice versa, according to their colony's needs. The proportion of foragers collecting pollen and the amount collected increased with increase of brood. Bees of colonies deprived of brood foraged less, and many former pollen-gatherers changed to collecting nectar only. Although brood in all stages stimulated pollen collection, in some circumstances larvae were more effective than pupae. The smell of the brood alone, and contact with bees tending it, were each partly responsible for foragers collecting pollen, but access to the brood was even more important. When access was denied foraging decreased and many pollen-gatherers switched to nectar gathering. Absence of a queen, irrespective of whether brood was present, increased nectar collection and decreased pollen collection, but did not affect the number of foragers. Giving pollen to a colony decreased pollen collection and increased nectar collection, but giving sugar had no influence on foraging.

11.10 FREE, J. B. (1967) The production of drone comb by honeybee colonies. *J. apicult. Res.* **5**, 177–182.

Drone-cell production reaches its annual peak in April and May. The amount of drone comb produced depends on the amount already present. The presence of an adult or immature queen stimulates worker-comb production. The absence of a queen does not stimulate drone-comb production, but the presence of developing queens does.

11.11 FREE, J. B. & RACEY, P. A. (1966) The pollination of *Freesia refracta* in glasshouses. *J. apicult. Res.* **5**, 177–182.

When foraging on large-flowered varieties of freesia, pollen-gathering honeybees were much more valuable pollinators than nectar-gatherers, and their numbers could be increased by feeding their colonies with sugar syrup. When foraging on small-flowered varieties of freesia, bees collecting nectar also pollinated the flowers. Nectar-gatherers and pollen-gatherers spent similar amounts of time per flower visit. Bees moved freely between freesia varieties of different colours, and so readily cross-pollinated them. Foragers tended to be more numerous near their colonies than elsewhere in the glasshouses.

11.12 FREE, J. B., NEEDHAM, P. H., RACEY, P. A. & STEVENSON, J. H. (1967) The effect on honeybee mortality of applying insecticides as sprays or granules to flowering field beans. *J. Sci. Fd Agric.* **18**, 133–138.

The effects on foraging bees of spray formulations of demeton-methyl and granular formations of disulfoton and phorate applied to field beans in flower were compared. Sprays killed honeybees foraging on the beans, whereas granules did not, either immediately after they were applied or later. After becoming systemic in plants the insecticides seemed harmless to bees.

Statistics Department

GENERAL PAPER

12.1 (BATEY, T.) & BOYD, D. A. (1967) The placement of fertilisers for potatoes. *N.A.A.S. q. Rev.* No. 78, 47–56.

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Research Papers

12.2 (Batey, T. *et al.*), Church, B. M. & Hills, M. G. (1967) Survey of Fertiliser Practice, 1966. London: Ministry of Agriculture, Fisheries and Food, 79 pp.

This report presents the basic information obtained from surveys of fertiliser practice done in 31 districts during 1966. Estimates of average manuring are given for tillage, leys and permanent grass, and for some individual crops, for different farming-type regions and for England and Wales as a whole:

	cwt/acre × 100		
	N	P_2O_5	K_2O
Tillage	58	40	42
Leys	53	36	23
Permanent grass	25	23	13
All crops and grass	44	33	27

Changes in fertiliser practice since 1962 are estimated by comparison with previous survey results. Between 1962 and 1966 nitrogen consumption per acre crops and grass increased by about a quarter, and changes in phosphate and potash consumption were small. On temporary and permanent grass nitrogen consumption per acre increased by almost 50%, and there were substantial increases in all farming-type regions. Changes in tillage manuring were relatively small, but there were substantial increases in the use of N on cereals, particularly in arable-farming districts. There was a fairly general small decrease in K per acre on tillage crops, associated with the increased use of "high N" type compounds.

Detailed results for the individual surveyed districts are given as an appendix to the report.

12.3 Church, B. M., Boyd, D. A., (Evans, J. A. & Sadler, J. I.) (1968) A type of farming map based on agricultural census data. *Outl. Agric.* **5**, 191–196.

The first detailed map showing the types of farming in England and Wales was published in 1941; this valuable map was necessarily and admittedly subjective. A new map (included with the paper) has now been prepared from farm census data, a task which has become practicable by use of electronic computers. Both the method of constructing the map and the characteristics of the areas distinguished are objectively defined. The paper draws attention to the advantages of agreeing a specification so that a map of this kind can be made periodically on a consistent basis to illustrate regional changes in farming pattern.

12.4 (Delany, M. J.) & Healy, M. J. R. (1967) Variation in the Long-tailed field-mouse (*Apodemus sylvaticus*) in south-west England. *J. Zool., Lond.* **152**, 319–332.

Measurements of four skull and five external characters were made on each of 277 specimens of *Apodemus sylvaticus* (L.) from the two Isles of Scilly (Tresco and St. Mary's) on which it occurs and from six localities in mainland Cornwall. The age of each individual was assessed by means of a tooth-wear character, and a regression adjustment was used to bring all the characters to a uniform age class.

A canonical analysis was made in an attempt to account for as much variation as possible between groups, using a few linear combinations of the original

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measurements. The greater part of the variance was contained in the first two canonical variates.

12.5 (DOUGLAS, J. W. B., ROSS, J. M.) & SIMPSON, H. R. (1967) The ability and attainment of short-sighted pupils. *Jl R. statist. Soc.* A **130**. (In the press.)

Short-sighted children are relatively hard-working and attentive at school. Although their non-verbal test scores resemble those of children with normal vision, they score considerably better in attainment tests. These findings are related to the age of onset of short sight and home circumstances. It is suggested that families with a history of short sight tend to acquire academic interests and greatly value non-manual or professional employment.

12.6 GOWER, J. C. (1967) A comparison of some methods of cluster analysis. *Biometrics*. **23**, 623–637.

Each individual of a multivariate sample may be represented by a point in a multi-dimensional Euclidean space. Cluster analysis attempts to group these points into disjoint sets which it is hoped will correspond to marked features of the sample. Different methods of cluster analysis of the same sample may assume different geometrical distributions of the points or may employ different clustering criteria or may differ in both respects. Three superficially different methods of cluster analysis are examined. The clustering criteria of all these methods, and several new ones derived from or suggested by these methods, can be interpreted in terms of the distances between the centroids of the clusters; the geometrical point distribution is found in most instances. The methods are compared, suggestions made for their improvement and some of their properties are established.

12.7 GOWER, J. C. (1968) A general coefficient of similarity and some of its properties. *Biometrics*. (In the press.)

A general coefficient of similarity between two units of a sample is defined. The matrix of similarities between all pairs of sample units is positive semi-definite (except possibly when there are missing values). This is an important property when the multi-dimensional representation of the sample is of interest; it also allows some inequalities relating the similarities among three individuals to be written down.

A hierarchical structure of characters is sometimes recognised and the definition is extended to cope with this.

12.8 GOWER, J. C. (1968) A survey of numerical methods useful in taxonomy. *Acarologia*. (In the press.)

The principles underlying some numerical methods useful in taxonomy are described. The mathematical treatment is elementary and is intended to give an introduction to the subject that can be supplemented by further reading. Classification, identification and the construction of phylogenies are discussed. As a first step towards improving the methods, attention is drawn to some of their deficiencies. Only by understanding the principles can taxonomists judge the usefulness, or otherwise, of numerical methods.

12.9 JONES, F. G. W., PARROTT, D. M. & ROSS, G. J. S. (1967) The population genetics of the potato cyst-nematode, *Heterodera rostochiensis*: mathematical models to simulate the effects of growing eelworm-resistant potatoes bred from *Solanum tuberosum* ssp. *andigena*. *Ann. appl. Biol.* **60**, 151–171.
(For summary see No. 8.16)

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12.10 LEECH, F. B., (MACRAE, W. D. & MENZIES, D. W.) (1968) Wastage and husbandry of calves in Britain. H.M.S.O. Report. (In the press.)

In a survey of calf-rearing made from October 1962 to September 1963 a stratified sample of 1567 farms was taken and detailed information on 40 000 calves born on these farms (or bought) during the surveyed period was obtained by officers of the Animal Health Division of the M.A.F.F.

The report covers factors affecting mortality, both of homebred and bought calves, and gives information on the main features of calf husbandry, feeding and housing and of the distribution of breeds in Britain, together with a picture of the traffic in calves.

It is estimated that on the average about 2% of the effort put into rearing calves, whether homebred or bought, was wasted by death of the calf during the period of the survey. Most herds had no losses, and most deaths occurred before calves were a month old. Only a very small percentage of farms suffered serious economic losses.

12.11 PATTERSON, H. D. (1967) Serial factorial design. *Biometrika*. (In the press.)

Serial factorial designs are designs for long-term experiments with one or more basic treatments repeated as separate factors every year. The designs are cyclic, with essentially the same structure in any period of successive years. For example, three rates of a single basic treatment (e.g. nitrogen fertiliser) can be tested each year in a design with just one replicate of the 27 combinations for any three successive years.

Methods are described for generating suitable randomised block designs for one or more basic treatments from residue classes of a polynomial ring.

12.12 PREECE, D. A. (1967) Incomplete block designs with $v = 2k$. *Sankhya* **29**, 305–316.

An incomplete block design is defined to be self-complementary if it is structurally the same as its complement. Examples are given of self-complementary partially balanced incomplete block designs with two associate classes. Procedures for examining whether a design is self-complementary are outlined. Balanced incomplete block designs with half the treatments in each block and with not more than 15 replications of each treatment are tabulated with an indication of which are self-complementary and which are not; many of the designs seem not to have been given previously.

12.13 PREECE, D. A. (1967) Cyclic generation of Robinson's balanced incomplete block designs. *Biometrics* **23**, 574–578.

Robinson (*Biometrics* **22**, 368–373) gave a list of the parameters of balanced incomplete block designs with no more than 100 units and with the blocks arranged in two orthogonal groups of sets (rows and columns), each set in either group consisting of one or more complete replications of the treatments. The present note gives a design for each of the possible sets of parameters, each design being cyclic with or without an invariant treatment. Four basic families of balanced incomplete block designs with double grouping of blocks into replications are described. Some designs with more than 100 units are listed.

12.14 PREECE, D. A. (1967) Nested balanced incomplete block designs. *Biometrika* **54**, 479–486.

A nested balanced incomplete block design is defined as a design with two systems of blocks, the second nested within the first (each block from the first

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system containing *m* blocks from the second), such that ignoring either system leaves a balanced incomplete block design whose blocks are those of the other system. A list is given of such designs having each treatment (or variety) replicated not more than fifteen times. The analysis is given for the general nested balanced incomplete block design; this analysis is an extension of that developed by Yates (1940) for the recovery of inter-block information in balanced incomplete block designs. A design based on a nested balanced incomplete block design was devised by Kleczkowski (1960) for laboratory studies on lesions produced by inoculating bean plants with tobacco necrosis virus.

12.15 (WEBBER, J.), BOYD, D. A. & HILL, J. R. (1968) Experiments on the P and K requirements of barley. *Exptl. Husb.* (In the press.)

Seventy-seven experiments testing P and K fertilisers on spring barley were done by N.A.A.S. Soil Scientists in England and Wales in 1964–66. The sites were restricted to particular soil series and were mainly on heavy-textured soils; almost all were fields in their second, third or fourth cereal crop. On average, 60 units P_2O_5/acre gave an increase of 0·9 cwt/acre, and 60 units K_2O/acre gave a decrease of 0·2 cwt/acre. Almost all the variation in response from site to site was attributable to experimental error, but some arose from small differences in response between years, and, for P, between soils and regions. Because response was so uniform, soil analysis was of no value. Similar results—small responses and little variation in response between sites—were found in other series of experiments on spring barley done in the past decade.

12.16 YATES, F. (1967) Discussion of reports on cloud seeding experiments. *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability* **5**, 395–397.

This paper contains comments on the reports of cloud seeding experiments which were presented to the Fifth Berkeley Symposium on Mathematical Statistics and Probability. Suggestions are made on methods of estimation for this type of data and on the determination of standard errors and tests of significance.

Field Experiments Section

RESEARCH PAPER

13.1 GARNER, H. V. (1967) Results of fertiliser experiments on carrots in 1941 and 1942. *J. agric. Sci., Camb.* **69**, 209–215.

In 1941 a co-ordinated scheme of field experiments on the fertiliser responses of carrots was drawn up by a committee of the Agricultural Research Council. The experimental design and field plans were provided from Rothamsted, and the field work was organised by the Advisory Soil Chemists of the Ministry of Agriculture. This paper is based on a report to the Agricultural Research Council by E. M. Crowther in 1943. In 1941 there were six centres testing N, P and K each at single and double rates; in 1942 the above nutrients were tested at one rate only, but agricultural salt was included in the factorial scheme. Most of the experiments were on sandy soils and light loams. In 1941 ammonium sulphate diminished yield at two centres and had negligible effects at the others; superphosphate increased yields slightly at most centres, and muriate of potash gave large increases at two. N tended to diminish plant numbers and K to increase them. The single dressing of fertiliser (0·2 cwt N, 0·4 cwt P_2O_5, 0·5 cwt K_2O/acre) was usually enough. In 1942 ammonium sulphate (0·3 cwt N/acre) had negligible

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effects on yield but was not harmful, and superphosphate (0·6 cwt P_2O_5/acre) increased the yield of roots by almost ½ ton/acre. Muriate of potash (0·9 cwt K_2O/acre) and agricultural salt (3·0 cwt/acre) were more effective, for each gave an average increase of about 1 ton of sound carrots per acre. There was a pronounced and consistent negative interaction between potash and salt. Nitrogen decreased and potassium increased the number of sound carrots. Nitrogen, potassium and salt usually increased the yield and number of split carrots, but only salt increased the proportion of splits in the total crop. Agricultural salt at 3 cwt/acre was only slightly less effective than 1½ cwt of muriate of potash.

Woburn Experimental Station

15.1 THOROLD, C. A. (1967) Black-pod disease of *Theobroma cacao*. *Rev. appl. Mycol.* **46**, 225–237.

This review mainly considers diseases caused directly by *Phytophthora palmivora* and secondarily indicates information available on some other disorders with which this fungus is associated.

Broom's Barn Experimental Station

BOOK

16.1 JONES, F. G. W. & DUNNING, R. A. (1968) Sugar beet pests. *Bull. Minist. Agric. Fish Fd. Lond.* No. 162 (revised), London: H.M.S.O.

GENERAL PAPERS

16.2 DUNNING, R. A. (1967) Wide seed spacing demands good pest control. *Fmg Wld* March.

16.3 DUNNING, R. A. & COOKE, D. A. (1967) Docking disorder. *Br. Sug. Beet Rev.* **36**, 23–29.

16.4 DRAYCOTT, A. P., (HODGSON, D. R. & HOLLIDAY, R.) (1967) Fertilisers in solution. *Agric. Prog.* **42**, 68–81.

16.5 HULL, R. (1967) Notes on plant pathology in the United States of America. *I.I.R.B.* **2**, 135–139.

16.6 SCOTT, R. K. (1968) Sugar-beet seed production. *Agric. Prog.* (In the press.)

RESEARCH PAPERS

16.7 BYFORD, W. J. (1967) The effect of some cultivation factors on the incidence of downy mildew in sugar-beet root crops. *Pl. Path.* **16**, 160–161.

The incidence of downy mildew in sugar-beet root crops was increased by large dressings of nitrogen, by decreases in plant population and by late sowing.

16.8 BYFORD, W. J. (1967) Field experiments on sugar-beet downy mildew (*Peronospora farinosa*). *Ann. appl Biol.* **60**, 97–107.

The numbers of sugar-beet plants infected with downy mildew in experimental crops increased slowly over a period of 8–15 weeks from late May. Few new infections appeared after the middle of August, although less than half the plants

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were then infected. Most infected plants recovered, and recovery was most rapid and complete in young plants, irrespective of the weather. Plants infected when young produced small roots, but their sugar content and juice purity at harvest were similar to those of uninfected plants. Plants first infected in late July and early August had the smallest sugar content and most juice impurities.

16.9 BYFORD, W. J. (1967) Host specialisation of *Peronospora farinosa* on *Beta*, *Spinacia* and *Chenopodium*. *Trans. Br. mycol. Soc.* **50**, 603–607.

The downy mildew fungi infecting *Beta* spp., *Spinacia oleracea* and *Chenopodium album*, are restricted in their host ranges, and the erection of three formae speciales within *Peronospora farinosa* (Fr.) Fr. is proposed.

16.10 BYFORD, W. J. & HULL, R. (1967) Some observations on the economic importance of sugar-beet downy mildew in England. *Ann. appl. Biol.* **60**, 281–296.

Sugar-beet downy mildew is most prevalent in England in the sugar-beet and mangold seed-growing area of South Lincolnshire and West Norfolk. The most widespread and severe recent outbreaks were in 1957, and in 1965, when 6412 acres were reported with more than 10% infected plants. The fungus usually overwinters in sugar-beet and mangold seed crops, and in England other ways of overwintering are seldom important. Steckling beds are infected in the autumn, and the disease may increase rapidly in the seed crop in early spring. Summer-sown stecklings get more downy mildew than stecklings sown in spring under a cereal cover crop, and direct-drilled seed crops get more downy mildew than transplanted crops.

16.11 DRAYCOTT, A. P. (1968) Field comparisons between compound and straight fertilisers for sugar beet. *Expl Husb.* No. 17. (In the press.)

Thirty-three experiments were made between 1961 and 1966 to compare mixtures of straight fertilisers with compounds supplying the same amounts of N, P and K. The experiments were on commercial farms in the major beet-growing areas of England and Scotland. In the early experiments straight fertilisers were slightly better than compound (in particular, the sugar content of the beet was larger). Later experiments failed to confirm this, and yields of beet and of sugar from straight and from compound fertilisers did not differ significantly. Analysis of roots grown with straight and with compound fertilisers showed no significant difference in root-juice purity. The results suggest that it is satisfactory to base recommendations for using certain compound fertilisers on the results of experiments testing only straight fertilisers.

16.12 HEATHCOTE, G. D. (1967) The overwintering of aphids and viruses on sugar-beet seed crops in England, 1963–1966. *Pl. Path.* **16**, 126–130.

Samples from approximately one-third of all English sugar-beet seed crops were checked for infesting aphids in late May, June or early July from 1963 to 1966. Sixty-eight per cent of all samples contained no aphids, 25% were infested, though lightly, with *Aphis fabae* and 7% with *Myzus persicae*, the main vector of beet viruses. *M. persicae* overwintered in appreciable numbers only in Kent in 1966; these infested crops were sprayed with insecticide once the aphids were discovered.

Sugar-beet seed crops in Britain are widely scattered and only about 3000 acres are grown. Producers of beet seed take adequate precautions to prevent virus disease from spreading, but should be encouraged to grow these crops away from sugar-beet root crops.

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16.13 HOOPER, D. J. & COOKE, D. A. (1967) Some observations on *Anomyctus xenurus* Allen 1940. *Nematologica* **13**, 320–321.

Anomyctus xenunus is reported for the first time in England. It was found in sandy soil previously cropped with sugar beet. The English specimens agree with the original description except that they are longer, the anterior part of the spear is curved and the oral opening has a hexaradiate appearance in face view.

16.14 HULL, R. (1968) The spray warning scheme for control of sugar-beet yellows in England. Summary of results between 1959–66. *Pl. Path.* **17**, 1–10.

Sugar-beet growers in England have been advised since 1959 to spray their crops with systemic insecticide to check the spread of yellows viruses when infestation with the vector aphids (mainly *Myzus persicae* Sulz.) in May and June reaches 0·25 aphids/plant. The data collected up to 1966 show that aphid infestation at any one time is not proportionally related to eventual yellows incidence. The graphs of mean aphid infestation and yellows incidence in different areas presented are a guide to issuing spray warnings.

16.15 HULL, R. & HEATHCOTE, G. D. (1967) Experiments on the time of application of insecticide to decrease the spread of yellowing viruses of sugar beet, 1954–1966. *Ann. appl. Biol.* **60**, 469–478.

Sprays of demeton-methyl decreased the spread of yellowing viruses by aphids in sugar-beet crops in England. Between 1957 and 1960, when "yellows" was prevalent, the incidence, assessed as "infected-plant-weeks", was decreased by 36–41% by one spray, and by 55% by two sprays, giving average yield increases of 1½ and 2 ton/acre of roots respectively. Between 1962 and 1966, when yellows spread less, a spray at the time when growers were advised to spray by the British Sugar Corporation decreased yellows incidence by 37%, whereas sprays 2 weeks earlier or later decreased it by 24 and 25% respectively.

Between 1958 and 1966 an annual average of 160 000 of the country's 440 000 acres of sugar beet has been sprayed, often to control *Aphis fabae* as well as to check the spread of yellows. A spray gives a profitable yield increase when yellows incidence in unsprayed plots is 20% at the end of August.

16.16 HULL, R. & WEBB, D. J. (1967) The effect of subsoiling and different levels of manuring on yields of cereals, lucerne and sugar beet. *J. agric. Sci., Camb.* **69**, 183–187.

The effect of subsoiling an old arable clay-loam soil at Broom's Barn Experimental Station was tested with a sequence of wheat, barley and sugar-beet crops, a lucerne ley and a sugar-beet test crop in the fourth year. Subsoiling increased the yield of each crop each year, averages over 3 years were: wheat, 0·6 cwt/acre of grain; barley, 0·4 cwt/acre; lucerne, 0·6 cwt/acre of dry matter. Average increases of sugar beet over 4 years were 0·7 tons/acre of roots or 2·1 cwt/acre of sugar; the increase was greatest (2·9 cwt/acre of sugar) in the first year.

The yield responses of all crops to extra fertiliser were no greater with than without subsoiling; in contrast, previous cropping and fertiliser usage influenced the optimum dressing of N for the sugar-beet test crop.

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Soil Survey of England and Wales

Books

17.1 Hall, B. R. & Folland, C. J. (1967) Soils of the South-west Lancashire Coastal Plain. Harpenden: Rothamsted Experimental Station, vii, 118 pp.

17.2 Hodgson, J. M. (1967) Soils of the West Sussex Coastal Plain. Harpenden: Rothamsted Experimental Station, viii, 148 pp.

Thesis

17.3 Thomasson, A. J. (1967) The water regimes and morphology of some fine-textured soils. M.Sc. Thesis, University of Nottingham.

General Papers

17.4 Ashley, G. D. & (Howard, P. J. A.) (1967) Field meeting in the Kent estuary and its tributary valleys. *Proc. North of England Soils Discussion Group* No. 3, 11–24.

17.5 Clare, K. E. (1967) The Soil Survey. *Agriculture, Lond.* **74**, 225–229.

17.6 Crampton, C. B. (1967) Soil development on tips in South Wales. *Sylva*, No. 47, 12–14.

17.7 (Lang, D. M.) & Corbett, W. M. (1966) Physical environment. In: Uboma—a socio-economic and nutritional survey of a rural community in eastern Nigeria.

17.8 Matthews, B. (1966) Radiocarbon dated postglacial land uplift in Northern Ungava, Canada. *Nature, Lond.* **211**, 1164–1166.

17.9 Pritchard, D. T. (1967) An all-plastic section funnel. *Analyst., Lond.* **92**, 199–200.

Research Papers

17.10 (Askew, G. P.) & Ashley, G. D. (1967) Characteristics of the soils of alluvial regions. *Proc. North of England Soils Discussion Group*, No. 3, 32–39.

An account of the formation, profile development and classification of alluvial soils with a section on problems of reclamation and utilisation.

17.11 Avery, B. W. (1965) Soil classification in Britain. *Pedologie, Gand., International Symposium* No. 3, 75–90.

Morpho-genetic systems of soil classification developed in Britain originated in attempts to group soil series that had been distinguished in soil surveys of areas in different parts of the country. The systems proposed resemble that of Aubert & Duchaufour. Soils in calcimorphic, brown earth, podzol and gley major groups, and their relationships with categories established elsewhere, are discussed.

17.12 Crampton, C. B. & (Jones, R. G.) (1967) The altitudinal zoning of grassland and soils on the Brecon Beacons in South Wales. *J. Br. Grassld Soc.* **22**, 46–52.

The altitudinal sequence of soils occurs lower on the north than on the south face of the Brecon Beacons, where the highest slopes of the north face are

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occupied by shallow, strongly leached rankers. Except on lower slopes, *Vaccinium*, *Calluna* and *Nardus* dominate the flora on each soil type. Unlike their distribution elsewhere, *Rhytidiadelphus* and *Hypnum* are here associated with gleyed soils. It is suggested that exposure and inaccessibility have limited hill grazing. The vegetation on the peaty gleyed soils is associated elsewhere with drier soils, formerly extensive on the Beacons, and preserved despite a changing edaphic environment. Some potentially nutritious pastures on the north face are too exposed to be grazed by sheep during winter, but *Vaccinium* pastures on lower slopes supply useful winter protein.

17.13 CRAMPTON, C. B. & (WEBLEY, D. P.) (1966) Soils and wireworm associations in Glamorgan. *Rep. Welsh Soils Discussion Group* No. 7, 46–53.

Wireworm infestation was surveyed during 1939–42 and correlated with a soil survey in Glamorgan. The most severe infestation is on fine-textured, but freely drained, soils over Lower Lias rocks occupying the coastal strip of the Vale. Less-severe infestation is associated with poorly drained and coarse-textured soils.

17.14 HALL, B. R. (1967) The soil associations of Furness. *Proc. North of England Soils Discussion Group* No. 3, 3–10.

The physiography, soils and vegetation of the five associations of Furness are described together with a short note on the Morecambe Bay Estuaries.

17.15 HODGSON, J. M., CATT, J. A. & WEIR, A. H. (1967) The origins and development of clay-with-flints and associated soil horizons on the South Downs. *J. Soil Sci.* **18**, 85–102.

17.16 PRITCHARD, D. T. (1967) Spectrophotometric determination of aluminium on soil extracts with xylenol orange. *Analyst, Lond.* **92**, 103–106.

A spectrophotometric method for determining aluminium in soil extracts with xylenol orange at pH 3·8 is described. Various extraction reagents can be used. Interference of iron (III) and iron (II) is eliminated with EDTA. Rectilinear calibration covers a range of 0–60 μg of aluminium. Typical results are shown for an iron–humus podzol. Recovery of added aluminium, and interference by anions and cations relevant to soil analysis, are described. The method is much more reliable than "lake" methods.

17.17 RUDEFORTH, C. C. (1966) Identification and distribution of soils in west central Wales. *J. agric. Soc. Univ. Coll. Wales, Aberyst.* **47**, 10–18.

Six soil associations are described and their relationships illustrated. A key for soil identification is provided, and the proportions of series within each unit is given.

17.18 RUDEFORTH, C. C. (1967) Upland soils from Lower Palaeozoic sedimentary rocks in mid-Wales. *Rep. Welsh Soils Discussion Group* No. 8, 42–51.

Properties of soils in the uplands of mid-Wales are discussed, with factors affecting their formation. Comparison with some lowland soils is made to establish the extent to which soil properties reflect upland influence.

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17.19 THOMASSON, A. J. & ROBSON, J. D. (1967) The moisture regime of soils developed on Keuper Marl. *J. Soil Sci.* **18**, 329–340.

The moisture regime of several representative profiles of the Worcester series developed on Keuper Marl are described and interpreted using a simple field technique supplemented by determinations of pore-space, moisture-content and moisture-release characteristics.

MAPS

17.20 HALL, B. R. (1967) Soil Map, 3rd Edition Sheet 74 (Southport) 1 : 63 360. Southampton: Ordnance Survey.

17.21 HALL, B. R. (1967) Soil Map, 3rd Edition Sheet 83 (Formby) 1 : 63 360. Southampton: Ordnance Survey.

17.22 HODGSON, J. M. (1967) Soil Map, 1 : 25 000 Sheet SU 90 (Bognor Regis. Southampton: Ordnance Survey.

17.23 HODGSON, J. M. (1967) Soil Map, 1 : 25 000 Sheet SU 70 & SU 80 (Chichester). Southampton: Ordnance Survey.

17.24 HODGSON, J. M. (1967) Soil Map, 1 : 25 000 Sheet SZ 79 & SZ 89 (Selsey Bill). Southampton: Ordnance Survey.

17.25 HODGSON, J. M. & KING, D. W. (1967) Soil Map, 1 : 25 000 Sheet TQ 00 and TQ 10 (Worthing). Southampton: Ordnance Survey.

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