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ABSTRACTS OF PAPERS

Physics Department

GENERAL PAPERS

- 1.1 MONTEITH, J. L. (1960). The physics of dew formation. [In Hebrew.] *Mada, Jerusalem*, **5**, 13.
- 1.2. PENMAN, H. L. (1960). Weather problems in agriculture. *Nature, Lond.* **187**, 995–996.
- 1.3. PENMAN, H. L. (1960). The general principles of irrigation. *Scot. Agric.* **42**, 140–142.

RESEARCH PAPERS

- 1.4. CURRIE, J. A. (1961). Gaseous diffusion in porous media. III. Wet granular materials. *Brit. J. appl. Phys.* **12**. (In the press.)

The diffusion of hydrogen through granular materials partly saturated with water was measured by a non-steady state technique previously described. The two types of sample used consisted of solid particles (unimodal pore-size distribution) and porous particles (bimodal pore-size distribution), and all measurements were made on samples being dried from saturation. Coefficients of diffusion D were calculated, and for the range over which the larger pores were emptying the empirical equation $D = D_0(\epsilon/\epsilon_0)^\sigma$ fitted all materials, where ϵ is the fractional air-filled volume, ϵ_0 is the volume occupied by the larger-pore phase, and where D_0 is the diffusion coefficient when only this phase is air-filled. For all materials $\sigma = 4$ whether the samples were uniform or of mixed sizes. No such relationship existed over the subsequent range in which the smaller pores were drained. Over this range D must be a function of at least five independent variables: the total porosity ϵ_T , the crumb porosity ϵ_c , the shape factor for the crumbs or inter-crumb pores k , the shape factor for the particles forming the crumbs or crumb pores k_c and the moisture content of the sample. The spatial distribution of pores within a porous medium can be as important as the sizes of the pores. The factors k and m , previously introduced as particle-shape factors, now have a greater significance as measures of the geometrical complexity of a porous system. Adding water can either increase or decrease the complexity, depending on the amount added and the nature of the system. The agricultural significance of diffusion between the crumbs (D_0) and within the crumbs (D_c) is discussed, and it is suggested that D_c , or its associated complexity factor k_c , might be used as an index of soil structure.

- 1.5. MONTEITH, J. L. (1960). Micro-meteorology in relation to plant and animal life. *Proc. Linn. Soc.* **171**, 71–82.

Micrometeorology is the study of atmospheric processes at the earth's surface. If the leaves of plants and the skins of animals are regarded as extensions of that surface, micrometeorological principles can help the biologist to investigate the influence of physical environment on living material. Two examples are considered in illustration. First, the surface temperature of plants and animals and the cooling produced by evaporation are discussed in terms of heat-balance equations. Second, it is shown that the uptake of carbon dioxide by a field crop can be measured by a micrometeorological technique.

- 1.6. MONTEITH, J. L. (1961). An empirical method for estimating long-wave radiation exchanges in the British Isles. *Quart. J. R. met. Soc.* **87**, 171.

From radiation measurements at Kew Observatory (tabulated by Lönnqvist), the effective emissivity of the atmosphere ϵ , defined as the ratio of

S

incoming long-wave radiation to black-body radiation at screen temperature, can be related to optical path m (cm.) by

$$\epsilon = 0.70 + 0.22 \log m$$

with standard deviation ± 0.018 . The relation between m and surface vapour pressure e (mb.) found from Belasco's (1952) air mass analysis is

$$\log m = 0.29\sqrt{e} - 0.80$$

giving

$$\epsilon = 0.53 + 0.065\sqrt{e}$$

almost the same as Brunt's equation from Benson data.

Net long-wave radiation L over short grass can be calculated from

$$L = (1 - C)(\epsilon - 1)\sigma T_A^4 + C\Delta L_1 - \Delta L_2$$

where C is fractional cloudiness; σT_A^4 is black-body radiation at screen temperature; ΔL_1 is a correction for the difference between T_A and cloud base temperature; and ΔL_2 for the difference between T_A and surface radiative temperature. From Roach's Kew data, $\Delta L_1 = -18$ cal.cm.⁻²day⁻¹; and ΔL_2 varies with season from -12 cal.cm.⁻²day⁻¹ (December) to $+20$ cal.cm.⁻²day⁻¹ (June). Throughout the British Isles, annual mean L with $C = 0$ is close to -200 cal.cm.⁻²day⁻¹, and for real values of C ,

$$L = 178C - 200 \text{ cal.cm.}^{-2}\text{day}^{-1}.$$

Estimated annual net (total) radiation is 29 k.cal.cm.⁻² with little variation over the British Isles.

1.7. MONTEITH, J. L. & SZEICZ, G. (1961). The radiation balance of bare soil and vegetation. *Quart. J. R. met. Soc.* **87**, 159.

Incoming short-wave radiation (S), reflected short-wave radiation (αS) and net radiation (R) were measured over bare soil and crops from 1957 to 1959, and net long-wave radiation (L) was deduced from

$$R = (1 - \alpha)S + L$$

For grass, α increased from 0.23 at solar elevation 60° to 0.28 at 20°, with daily mean 0.26. For bare soil, the corresponding increase was from 0.16 to 0.19, with mean 0.17. In mid-June L for bare soil decreased from -0.1 cal.cm.⁻²min.⁻¹ during the night to -0.4 cal.cm.⁻²min.⁻¹ in the early afternoon. For long grass, in August, the corresponding change was from -0.05 to -0.22 cal.cm.⁻²min.⁻¹. Under clear skies the incoming long-wave component varied much less than the outgoing component, and net flux L was closely related to surface temperature.

With a "heating coefficient" $\beta = -dL/dR$, the observed linear dependence of R on S in the absence of cloud may be expressed as

$$R = S(1 - \alpha)/(1 + \beta) + L_0$$

where, formally, $R = L_0$ when $S = 0$. For grass, sugar beet and potatoes, β lay between 0.15 and 0.22, with a variation which may depend on wind speed rather than on crop. The value for dry bare soil was higher (0.41) because there was greater surface heating.

Measurements under clear skies and over grass at Cambridge and Kew agree well with Rothamsted values ($\beta = 0.22$, $L_0 = -5.9$ cal.cm.⁻²hr.⁻¹). Over Nebraska prairie, $\beta = 0.25$, $L_0 = -4.5$ cal.cm.⁻²hr.⁻¹ from selected observations during Projects Great Plains and Prairie grass.

1.8. PENMAN, H. L. (1960). Evaporation. *In: British manual of water supply practice*. London, Institution of Water Engineers.

After setting out the water balance equation for a catchment area the individual terms are considered separately. Evaporation is discussed, first through the statistical approaches of Turc and Tamm, and then via Thornthwaite to more purely physical approaches. A dozen examples are given of new computations of mean monthly potential transpiration for representative sites in the British Isles, and a complete table of mean annual rainfall and mean annual run-off for all British catchments having more than 4 years of records. As expected, the annual value of rainfall *minus* run-off is usually less than the calculated potential transpiration because of checks to transpira-

tion during dry summers, and the soil physics of this is considered with special reference to the ideas of Veihmeyer. The water balance of two catchments is analysed. The first, for the Stour, is a review of old work: the second, for an area in the Harz mountains in Germany, is new. Five years' measurements give the mean annual difference between rainfall and run-off as 22.8 inches for a forest area and 20.6 inches for a grass area. Calculation of potential transpiration, from weather data taken in the neighbourhood, gives a mean annual value of 22.6 inches, which is brought to 20.1 inches if evaporation is assumed to be zero during the months when the grass is under snow.

Chemistry Department

GENERAL PAPERS

- 2.1. COOKE, G. W. (1960). The use of fertilisers on grassland. *S.C.I. Monogr. no. 9* ("Chemical Aspects of the Production and Use of Grass"), pp. 5-18.
- 2.2. COOKE, G. W. (1960). Optimum fertiliser dressings. *J. R. agric. Soc.* **121**, 21-33.
- 2.3. COOKE, G. W. (1960). Soils and fertilisers. *J. R. agric. Soc.* **121**, 170-191.
- 2.4. COOKE, G. W. (1960). Några synpunkter på kemiska undersökningar av jordens bördighet. (Some chemical aspects of soil fertility research.) [In Swedish.] *K. Skogs-och LantbrAkad. Tidskr.* **99**, 151-170.
- 2.5. COOKE, G. W. (1960). The right place for fertilisers. *Pract. Power Fmg.* **24** (no. 3), 39-47.
- 2.6. MATTINGLY, G. E. G. (1959). Crops. *Rep. Progr. appl. Chem.* **44**, 268-276.
- 2.7. WIDDOWSON, F. V. (1960). Fertiliser placement. *N.A.A.S. Quart. Rev.* no. 48, 147-150.

RESEARCH PAPERS

- 2.8. ARNOLD, P. W. (1960). Potassium-supplying power of some British soils. *Nature, Lond.* **187**, 436-437.

British soils containing similar amounts of total K vary greatly in their ability to release non-exchangeable K. For soils which had not received heavy K manuring the K released to crops increased with increases in the amounts of fine clay ($<0.3 \mu$) and also with the K content of the fine clay. Amounts on the coarse clay ($0.3-2.0 \mu$) were poorly correlated with K-supplying powers of the soils. Only one soil, derived from glauconitic Malmstone, released significant amounts of K from large particles.

- 2.9. ARNOLD, P. W. (1960). Nature and mode of weathering of soil-potassium reserves. *J. Sci. Fd Agric.* **11**, 285-292.

In most partially weathered mineral soils only a small part of the total K is readily exchanged with other ions; the bulk occurs in non-exchangeable (or difficultly exchangeable) forms in potash feldspars, micas and micaceous clays, all of which are potential sources of K for plants. Some of the principles underlying the weathering processes in feldspars, trioctahedral and dioctahedral micas are discussed. The ease with which freshly cleaved potash feldspar releases K to water does not indicate that feldspar weathers easily; in soil feldspar is protected by a surface covering of its own decomposition products. Trioctahedral micas are less stable to weathering than dioctahedral micas, particularly during the early stages of K-depletion; the stabilities of these

two main groups of micas differ more than can be accounted for in terms of Fe^{++} contents. For micas and micaceous clays the relationships between parent lattices and weathering products must depend very largely on the extent to which layer-charges have decreased on weathering.

- 2.10. BREMNER, J. M. (1960). Determination of nitrogen in soil by the Kjeldahl method. *J. agric. Sci.* **55**, 11–33.

The reliability of the Kjeldahl method for determining N in soils was investigated. The same result was obtained by a variety of procedures, including methods which recovered various forms of N not determined by the common Kjeldahl methods used for analysing soils. It was concluded that little, if any, of the N in the soils examined was as highly refractory N compounds or as compounds containing N–N or N–O linkages. Results by the A.O.A.C. method of determining N in soils were 10–37% lower than those by other methods tested, but satisfactory results were obtained by this method by increasing the period of digestion recommended. Ammonium-N fixed by clay minerals is determined by the Kjeldahl method. Se and Hg are more effective than Cu for catalysing Kjeldahl digests of soil. Conditions leading to loss of N in using Se are defined, and difficulties in using Hg are discussed. The most important factor was temperature of digestion with H_2SO_4 , this is controlled largely by the amount of K_2 (or Na_2) SO_4 used. The period of digestion required depended on the concentration of K_2SO_4 ; with low concentration (e.g., 0.3 g./ml. of H_2SO_4) it is necessary to digest for several hours; but with high concentrations (e.g., 1.0 g./ml. H_2SO_4) short digestion was enough. Catalysts affected the rate of digestion with low but not with high salt concentrations. N is lost from digestions above 400°. The amounts of H_2SO_4 consumed by various mineral and organic soils during digestion were measured. Semi-micro Kjeldahl methods gave the same values for soil N as macro methods.

- 2.11. BREMNER, J. M. & JENKINSON, D. S. (1960). Determination of organic carbon in soil. I. Oxidation by dichromate of organic matter in soil and plant materials. *J. Soil Sci.* **11**, 394–402.

Organic C contents of a range of soils and of various materials (mostly from plants) were determined by the titrimetric methods of Tinsley and Walkley and Black, they were compared with those obtained by Shaw's wet combustion method. Tinsley's method gave more reliable results with soils than Walkley and Black's method; neither was satisfactory for precise work. Both give high results with organic materials less oxidised than elemental C and low results with organic materials more oxidised, but this effect was masked with materials that do not react completely under Walkley and Black conditions. Quantitative results were obtained on a range of whole plant materials with both Tinsley's and Walkley and Black's methods. C contents determined by Tinsley's method for a range of pure organic compounds agreed with theory. Tinsley's method does not give quantitative results with certain soils, partly because of the oxidation level of the organic matter in them, and partly because oxidation is incomplete.

- 2.12. BREMNER, J. M. & JENKINSON, D. S. (1960). Determination of organic carbon in soil. II. Effect of carbonised materials. *J. Soil Sci.* **11**, 403–408.

A variable, and often substantial, amount of the C in carbonised materials, like coal, charcoal and graphite, is oxidised when these materials are treated with acid dichromate in determining soil organic C. These methods cannot be used to detect carbonised materials in soil, or to discriminate between C in carbonised materials and C in soil humus.

- 2.13. JENKINSON, D. S. (1960). Scintillation counting of carbon-14. *Nature, Lond.* **186**, 613–614.

A method was developed for counting high activities of ^{14}C which is rapid, precise and independent of the chemical form of the ^{14}C .

- 2.14. RODRIGUEZ, J. & MATTINGLY, G. E. G. (1960). Estimation of potassium in soils by determination of ^{40}K content. *J. Sci. Fd Agric.* **11**, 717-721.

The K contents of 38 soils from Great Britain and Spain were estimated by determining their count rates in a cylindrical Geiger-Müller tube. The count rate was converted to % K from a calibration curve obtained with mixtures of powdered quartz and minerals of known K content and density. The mean amount of K in 26 soils from Central, Eastern and Southern England was 0.19% K higher by counting than by chemical analysis because they contained other radioactive elements. The radioactivity of these soils, other than that from K, was equivalent to approximately U 2.5 p.p.m. and Th 18 p.p.m. Results by chemical analysis and by counting differed more with 12 soils from Scotland, Wales and Spain than with soils from England.

The standard error of the mean of duplicate estimations of the K content of soils was about $\pm 0.075\%$ K for the radio-chemical method, and ± 0.023 to $\pm 0.026\%$ K for two chemical methods.

- 2.15. WIDDOWSON, F. V., PENNY, A. & COOKE, G. W. (1960). The value of calcium nitrate and urea for main-crop potatoes and kale. *J. agric. Sci.* **55**, 1-10.

Twenty-two experiments on main-crop potatoes and seven experiments on kale in 1955-57 compared calcium nitrate and ammonium sulphate applied to the seedbeds before planting; urea was also tested in 15 of the potato experiments and five of the kale experiments in 1956-57. Calcium nitrate usually gave less potatoes than ammonium sulphate, particularly with the high dressings. Smaller yields with the nitrate were usually associated with severe checks to early growth occurring during dry springs and with dressings concentrated too close to the seed, but yields were also smaller at some centres where early growth was not checked. Calcium nitrate and ammonium sulphate were roughly equivalent for kale when nitrate did not damage germination; but heavy dressings of nitrate in the seedbed greatly decreased kale plant numbers when there was little rain after sowing. Granulated urea tested in 1956 contained 4.5% of biuret, and it delayed emergence and affected plant establishment seriously in several of the potato experiments; damage increased with the level of manuring and was accentuated when dressings were broadcast over furrows before hand-planting. Yields given by this batch of urea were less than with other N fertilisers, and when 1.5 cwt. N/acre was applied they were less than with no nitrogen at all. Purer crystalline urea (having less than 1% of biuret) used in the 1957 experiments did not affect emergence of potatoes and gave yields similar to those from ammonium sulphate. There were similar effects in the kale experiments; granulated urea containing much biuret damaged germination severely in 1956; the purer products containing little biuret used in later years affected plant numbers at one centre in 1957 and at the single 1958 centre. Where the establishment of kale was unaffected, urea and ammonium sulphate gave similar yields. Dressings applied partly to the seedbed and partly in mid-season gave slightly higher average yields of kale than an equivalent total amount of N all applied before sowing.

- 2.16. WIDDOWSON, F. V. & SHAW, K. (1960). Comparisons of casein and formalised casein with ammonium sulphate, calcium nitrate and urea for Italian ryegrass. *J. agric. Sci.* **55**, 53-59.

Single dressings of ammonium sulphate and of casein were of similar value at each of three cuttings of Italian ryegrass in 1956. Casein treated with formalin released N much more slowly and was of little value in the early part of the growing season. Formalised casein produced significantly higher yields than casein at the later cuttings in 2 years, but aggregate increases from this material were much less than those from untreated casein in each season. Formalised casein increased yields considerably in the year after application. Single dressings of formalised casein were also compared with "repeated" dressings of ammonium sulphate, calcium nitrate and urea, in which the same total quantity of N was divided equally between cuttings. Formalised casein produced much lower yields than these "repeated" dressings in the early

part of the season, but was of only slightly less value at the last cut in 1956 and gave the highest yield at the final cut in 1957. Aggregate yields from repeated dressings of inorganic N fertilisers were higher than those given by single dressings of either form of casein. Urea applied before sowing (at 0.5 cwt. N/acre) affected germination and plant establishment slightly. Under dry conditions both urea and calcium nitrate gave higher yields than ammonium sulphate, but with adequate rain the three fertilisers behaved similarly.

- 2.17. WILLIAMS, R. J. B., STOJKOVSKA, A., COOKE, G. W. & WIDDOWSON, F. V. (1960). Effects of fertilisers and farmyard manure on the copper, manganese, molybdenum and zinc removed by arable crops at Rothamsted. *J. Sci. Fd Agric.* **11**, 570-575.

The Cu, Mn, Mo and Zn contents of five different crops grown in an experiment testing farmyard manure (FYM) and N, P and K fertilisers were measured. Fertilisers and FYM had similar and rather small effects on the percentages of micro-nutrients in the crops; the total amounts of micro-nutrients removed were related mainly to the yields. Clover and kale removed much more Mo than did the other crops; clover had a high requirement for all the micro-nutrients examined. The fertilisers used supplied only insignificant amounts of micro-nutrients, whereas the 15 tons/acre of FYM supplied as much Cu, Mn and Mo as the five crops together removed, and nearly as much Zn. The soil used contains enough of these micro-nutrients for very many rotations of arable crops provided the total quantities present become available. Although the FYM dressing used supplied more of each of the micro-nutrients than was needed by any of the crops grown, it affected crop growth by the N, P and K it supplied and by improving physical conditions in the soil.

Pedology Department

GENERAL PAPER

- 3.1. STEPHEN, I. (1960). Clay orientation in soils. *Sci. Progr. Lond.* **48**, 322-330.

A review of recent work with 35 references. Optical anisotropy of clay aggregates in sedimentary deposits and soils results from the orientation of the individual platelets. Several distinctive patterns of clay morphology exist in undisturbed soils, and detailed investigation of the micromorphology yields valuable information on the conditions of deposition of the parent material and on the genesis of the soils, and assists in their classification.

Soil Microbiology Department

GENERAL PAPERS

- 4.1. JACKSON, R. M. & BROWN, M. E. (1960). Plant roots and soil micro-organisms. *Chem. & Ind.* **6**, 140-142.
- 4.2. NUTMAN, P. S. (1960). The place of the nodulated legume in agriculture. *N.A.A.S. Quart. Rev.* **49**, 20-26.

RESEARCH PAPERS

- 4.3. BROWN, M. E. (1961). Stimulation of streptomycin-resistant bacteria in the rhizosphere of leguminous plants. *J. gen. Microbiol.* (In the press.)

Bacteria resistant to streptomycin and rose bengal were preferentially stimulated in the rhizospheres of several plant species. Leguminous plants were the most effective stimulants, and clover plants as young as 6 days had some effect. The separate and combined effects of rose bengal and streptomycin in the isolation medium were examined. Rose bengal alone had little effect on bacterial numbers, whereas streptomycin alone decreased them.

The two substances together affected rhizosphere counts strikingly but irregularly. The bacteria from rhizosphere and soil were grouped according to their nutritional requirements. Chromogenic bacteria with simple requirements were the most abundant resistant forms in the rhizosphere, and a species of *Flavobacterium* was especially favoured.

- 4.4. GIBSON, A. H. & NUTMAN, P. S. (1961). Studies on the physiology of nodule formation. VII. A reappraisal of the effect of pre-planting. *Ann. Bot.* **24**, 420-433.

The time the first nodule forms is advanced and the total number of nodules formed is depressed by growing *Trifolium pratense* L. and *Medicago sativa* L. on agar slopes previously planted with seedlings of these species. These effects were at first attributed to root secretions, which at low concentration hasten initial nodulation but at higher concentrations inhibit nodule formation. Further work has shown that initial nodulation is stimulated because the preplant removes traces of nitrate from the medium. The amount of nitrate in the tap water used to prepare the medium (6.5 p.p.m. N) increases the number of nodules formed on the control plants, and this effect explains to a considerable extent the depression of nodule numbers by preplanting. Initial nodulation was delayed by small amounts of nitrate and nitrite, but not by other forms of combined nitrogen (ammonium, asparagine and urea). All forms of combined nitrogen tested increased the number of nodules formed over a period of 8 weeks when supplied at an initial concentration of 20 p.p.m. N.

- 4.5. NUTMAN, P. S. (1961). Variation in symbiotic effectiveness in subterranean clover (*Trifolium subterraneum* L.) *Aust. J. agric. Res.* (In the press.)

The symbiotic effectiveness of 15 varieties and of four tetraploid lines in association with several strains of nodule bacteria was examined. Small differences in yield occurred between host varieties; the varietal order of response depended somewhat on the bacterial strain. Hybridisation between varieties increased yields slightly in F_2 , less in F_3 and not in F_4 . With one doubtful exception, all attempts to alter effectiveness by selection or breeding within hybrid material failed.

- 4.6. SKINNER, F. A. & WALKER, N. (1961). Growth of *Nitrosomonas europea* in batch and continuous culture. *Arch. Mikrobiol.* **38**, 339-349.

A clear medium was used to grow pure cultures of *Nitrosomonas europea* in flasks and in the continuous-culture apparatus.

Of several metallic ions examined in flask cultures of *Nitrosomonas*, Fe at 2 p.p.m. and Co, Mn and Zn at 1 p.p.m. were not toxic, Ni and Cr at concentrations greater than 0.25 p.p.m. inhibited growth; Cu stopped growth completely at 0.5 p.p.m. and inhibited it at 0.1 p.p.m. Stainless steel of the specification EN58B did not affect growth.

In the continuous-culture vessel *Nitrosomonas* showed a growth response to Fe only when the population exceeded about 500×10^6 organisms/ml. The minimum doubling time was about 8 hours in flasks and 11 hours in the culture vessel. With effective aeration and automatic pH control, cultures of *Nitrosomonas* were grown successfully in continuous culture, and gave a yield of 2.14 g. dry weight of bacteria from 30 litres of culture in 5 days.

Botany Department

GENERAL PAPERS

- 5.1. (BLACK, J. N.) & WATSON, D. J. (1960). "Photosynthesis and the theory of obtaining high crop yields, by A. A. Niciporovic." An abstract with a commentary. *Field Crop Abstr.* **13**, 169-175.
- 5.2. HUMPHRIES, E. C. (1960). Effects of mutilation of the root on subsequent growth. *Sci. Hort.* **14**, 42-48.

RESEARCH PAPERS

- 5.3. HUMPHRIES, E. C. (1960). Inhibition of root development on petioles and hypocotyls of dwarf bean (*Phaseolus vulgaris*) by Kinetin. *Physiol. Plant.* **13**, 659-663.

Kinetin inhibits root formation on petioles and hypocotyls of dwarf bean. It induces callus on petioles but not on hypocotyls. When kinetin is subsequently withheld, normal roots originate from the callus. Kinetin counteracts the effect of naphthalene-acetic acid in inducing root formation.

- 5.4. HUMPHRIES, E. C. & FRENCH, S. A. W. (1960). The effect of gibberellic acid on leaf area and dry matter production in Majestic potato. *Ann. appl. Biol.* **48**, 177-188.

When gibberellic acid (50 p.p.m. in aqueous solution) was sprayed twice or six times at weekly intervals on potato plants (var. Majestic) with a low or high nitrogen supply it did not affect rate of leaf production on the main axis, but caused earlier senescence of leaves, especially with the more frequent spraying, and inhibited leaf production and growth on laterals of the high nitrogen plants at nodes 10 and 11, but not at other nodes. This central region of the stem appears to have a low growth potential, probably because it lies midway between two zones of active growth, viz., the basal branches and the younger leaves on the main stem. Competition between these is increased by gibberellic acid. Gibberellic acid increased leaf area even when lack of nitrogen was restricting growth, but this did not produce extra dry matter. Tuber weight was increased more in high nitrogen plants by two sprayings than by six sprayings. The net assimilation rate of low-nitrogen plants was halved by spraying, but was not changed in high-nitrogen plants, where the value was similar to that of low-nitrogen control plants. The high-nitrogen plants had absorbed nearly all the available nitrogen between the second and third harvests, but plants treated with gibberellic acid, nevertheless, had more total dry weight and tuber dry weight than the controls. The nitrogen content of the leaves expressed on an area basis was lower in sprayed plants and, with continued spraying, fell at the third harvest to equal that of low-nitrogen plants. Evidently, the effect of gibberellic acid depended on the interaction between the rate of application and the nitrogen supply, but further work is necessary to define the conditions that give the maximal effect on dry-matter production.

- 5.5. HUMPHRIES, E. C. & MACIEJEWSKA-POTAPCZYK, W. (1960). Effects of indoleacetic acid, naphthalene-acetic acid, and kinetin on phosphorus fractions in hypocotyls of dwarf bean (*Phaseolus vulgaris*). *Ann. Bot. Lond. N.S.* **24**, 311-316.

Total phosphorus and orthophosphate in hypocotyls of dwarf bean were increased by NAA and unaffected by kinetin. Acid-soluble bound P, representing several different compounds, was increased by NAA and by higher concentrations of kinetin. Ribonucleic acid phosphorus was greatly increased by NAA alone and slightly inhibited by kinetin (1 mg./l.). The large effect of NAA is probably associated with increased cell number.

Kinetin strongly inhibited formation of roots in bean hypocotyls, apparently not by inhibiting cell division, but by influencing the kind of cell produced.

- 5.6. THORNE, G. N. (1960). Variations with age in net assimilation rate and other growth attributes of sugar-beet, potato and barley in a controlled environment. *Ann. Bot. Lond. N.S.* **24**, 356-371.

When sugar beet, potato and barley plants were grown in a controlled environment, net assimilation rate based on leaf area of all species fell approximately linearly with time by 4% of the initial value per week for sugar beet, and by 15% per week for potato and barley. Net assimilation rate based on leaf weight and leaf nitrogen content decreased at about 15% of the initial

value per week for all species. Mean values for potato and barley were similar and less than for sugar beet.

Relative growth rate, relative leaf growth rate and leaf-area ratio fell with time at similar rates for all species.

- 5.7. THORNE, G. N. (1961). Effects of age and environment on net assimilation rate of barley. *Ann. Bot. Lond. N.S.* **25**, 29–38.

Net assimilation rate (E) of barley grown in pots in the open at Ottawa decreased during June and July by 77%, and that of similar plants transferred to a constant environment for the 2 weeks during which E was determined decreased by 90%. Thus, the fall in E with age was partially masked outdoors by the improvement of environmental conditions during the experiment. Plants grown continuously in the constant environment had lower E , greater leaf area and dry weight and earlier ear emergence than plants of similar age transferred to the constant-environment rooms from outdoors.

- 5.8. THURSTON, J. M. (1961). The effect of depth of burying and frequency of cultivation on survival and germination of seeds of wild oats (*Avena fatua* L. and *Avena ludoviciana* Dur). *Weed Res.* **1**, 19–31.

Seeds of *A. fatua* and *A. ludoviciana* were sown in small field-plots at Rothamsted and subjected to 5 different regimes of depth and frequency of cultivation for 3 years, after which all plots were dug to 15 cm. in spring and autumn for the next 4 years.

Seed survival and germination were influenced more by species than by cultivations. The maximum survival was 61 months for *A. fatua* and 33 months for *A. ludoviciana*. *A. fatua* germinated in spring and autumn, *A. ludoviciana* in winter. Most seedlings of *A. fatua* appeared in the second spring, but 80% of seedlings of *A. ludoviciana* came in the first autumn and winter. Less than 20% of the seeds sown produced seedlings, although viability remained good throughout 8 years' dry storage. Seeds of *A. fatua* survived slightly longer at 15 cm. than in the top 5 cm. of soil; *A. ludoviciana* was less affected by depth of burying.

- 5.9. WHEELER, A. W. (1960). Changes in a leaf-growth substance in cotyledons and primary leaves during the growth of dwarf bean seedlings. *J. exp. Bot.* **11**, 217–226.

A leaf-growth substance, active in the etiolated dwarf French bean leaf disk test and with the same R_f value as gibberellic acid on chromatograms run with isopropanol-ammonia-water, was found in the acidic fraction of ethyl acetate extracts from dwarf French bean (*Phaseolus vulgaris*) primary leaves and cotyledons. The amount of this leaf-growth substance per cotyledon or primary leaf reached a maximum then fell; the maximum content in the primary leaves occurred later than in the cotyledons, and coincided with the maximum growth rate of the primary leaves. Leaf-growth substances did not accumulate in primary leaves of dark-grown plants.

Biochemistry Department

GENERAL PAPERS

- 6.1. PIRIE, N. W. (1960). New foods for world needs. *Roy. Soc. Health J.* **80**, 198–203.
- 6.2. PIRIE, N. W. (1960). New sources of food. *Discovery*, **21**, 374–379.
- 6.3. PIRIE, N. W. (1960). Water hyacinth: a curse or a crop? *Nature, Lond.* **185**, 116.
- 6.4. PIRIE, N. W. (1960). Lung cancer and tobacco mosaic virus. *Lancet*, 26 March 1960, 707.

- 6.5. PIRIE, N. W. (1960). The present position and future needs of research on leaf protein. *Proc. Conf. on Protein Needs, Washington DC Nat. Acad. Sci.-Nat. Res. Council*, 21-32. (In the press.)
- 6.6. PIRIE, N. W. (1961). The maintenance of life in space ships: synthesis recycling, and the steps towards a microcosm. *In: The Biology of space travel* (Inst. Biol.). (In the press.)
- 6.7. PIRIE, N. W. (1961). Protein foods from plants. *Span*, 4, 21-23; *Sci. World*, 5, 20-22.
- 6.8. PIRIE, N. W. (1961). A biochemical approach to world nutrition. *May & Baker Lab. Bull.* (In the press.)
- 6.9. PIRIE, N. W. (1961). The production and use of leaf protein as a human food. *Far East Trade*, 16, 310-311.

RESEARCH PAPERS

- 6.10. BYERS, M. (1961). Extraction of protein from the leaves of some plants growing in Ghana. *J. Sci. Fd Agric.* 12, 20-30.

Extracts were made from the fresh leaves of 60 tropical species by mincing them and squeezing the resultant pulp through cotton cloth. Total-N and protein-N determinations were made on the extracted juice, and the percentages of total-N and protein-N extracted, and total-N remaining in the fibre were calculated. Small samples of crude protein were precipitated from the sap at 80° and analysed for total N.

The results are classified according to the extractability of protein-N from the leaf and to the protein content of the product isolated. The legumes, most of which were specially grown, were the best sources of easily extractable and good-quality protein, but good results were also obtained with a few of the more common weeds, which in general yielded more protein than the leaves from existing crops. Leaves of some species contained much mucilage or fibre, and it was difficult to make adequate extracts from them by the method described.

- 6.11. DAVYS, M. N. G. & PIRIE, N. W. (1960). Protein from leaves by bulk extraction. *Engineering*, 190, 274-275.

The principles governing pulping and pressing moist fibrous material such as fresh leaves are set out, and descriptions are given of the pulper and press now in use.

- 6.12. FESTENSTEIN, G. N. (1961). The extraction of protein from green leaves. *J. Sci. Fd Agric.* (In the press.)

Extraction of nitrogenous material (especially protein nitrogen) from leaves of different species has been studied using the Pirie steel press, which grinds small quantities of leaves by forcing them through a narrow slot. Extraction of young tobacco leaves is comparable with high-speed maceration, and sedimentable material is more dispersed; extraction under alkaline conditions is increased because chloroplasts are more dispersed. 90-95% of nitrogenous material is extracted after using detergents to release nitrogen from residual fibre after initial extraction in the press; less nitrogen is released from macerated fibre.

- 6.13. HOLDEN, M. (1961). The breakdown of chlorophyll by chlorophyllase. *Biochem. J.* 78, 359-364.

1. Soluble chlorophyllase preparations were made from sugar-beet leaves, which have the highest activity of all species tested.

2. For the partly purified enzyme the optimum conditions for enzyme action are pH 7.7 at 25° and an acetone concentration of 40%.

3. When dark-grown pea seedlings with very low chlorophyllase activity were transferred to daylight the activity rose in 48 hours to a level comparable with that of light-grown seedlings.

- 6.14. MANN, P. J. G. (1961). Further purification and properties of the amine oxidase of pea seedlings. *Biochem. J.* (In the press.)

Preparations of pea-seedling amine oxidase, obtained by a method previously described, were further purified by column chromatography on hydroxyapatite and DEA-cellulose to give an 880-fold purification. The final preparations were pink solutions with maximum absorption at 500 m μ . This was the only band detected in the visible part of the spectrum. The colour was discharged by sodium dithionite and by 1:4-diaminobutane, under anaerobic conditions and restored by oxygenation. The colour was also discharged by hydrazine; this reaction was not reversed by oxygenation. The preparations contained 0.08–0.09% of copper. It is suggested that the pink colour comes from a copper complex of a carbonyl compound and that this complex forms the prosthetic group of the enzyme and undergoes a cycle of reduction and re-oxidation during the catalytic activity.

- 6.15. MANN, P. J. G. (1960). Further purification and properties of the amine oxidase of pea seedlings. *Biochem. J.* **76**, 44 P.

- 6.16. MORRISON, J. E. & PIRIE, N. W. (1961). The large-scale production of protein from leaf extracts. *J. Sci. Fd Agric.* **12**, 1–5.

Juice from fresh, pulped leaves is freed from most of the starch grains, fibre and detritus and coagulated quickly with steam. The protein coagulum is filtered off, washed with water at pH 4 and pressed into blocks with 30–40% dry matter. In this form it keeps under refrigeration.

Texture, colour and nutritive value of the final product are determined by the conditions of drying. The precautions needed during drying, especially freeze-drying, are described. The products are fairly stable at room temperature, but lipids have to be removed before the protein will keep permanently. The conditions for doing this by acetone extraction are described.

The composition of the protein and the uses to which it can be put are described briefly.

- 6.17. PIRIE, N. W. (1961). The disintegration of soft tissues in the absence of air. *J. agric. Engng Res.* (In the press.)

A device is described in which, with exclusion of air, soft materials are pulped by being forced through a slot of adjustable width at high pressures.

- 6.18. SINGH, N. (1960). Differences in the nature of nitrogen precipitated by different methods from wheat leaf extracts. *Biochim. biophys. Acta*, **45**, 422–428.

More nitrogen is always precipitated from a leaf extract by trichloroacetic acid than by boiling the extract. When the extract is coagulated by slow heat much nucleic acid is lost, probably from the activity of leaf RNase during heating. If the coagulation is done by rapid heating the enzymes are inactivated, but some nucleic acid remains uncoagulated due to partial disruption of nucleo-proteins. Trichloro-acetic and perchloric acids behave similarly and precipitate N which consists of protein N as well as nucleic acid N. Uranyl TCA precipitates some TCA soluble polynucleotides and also renders some lipoprotein-polynucleotide complex insoluble in fat solvents.

Plant Pathology Department

GENERAL PAPERS

- 7.1. BAWDEN, F. C. (1960). Plant viruses: what they are and what they do. *Proc. roy. Instn G.B.* **38**, 50–69.
- 7.2. BAWDEN, F. C. (1960). Plant diseases. *Bull. atom. Scient.* **16**, 247–250.
- 7.3. BAWDEN, F. C. (1960). Soil-borne viruses. *Agriculture, Lond.* **67**, 387–391.

- 7.4. GLYNNE, MARY D. (1960). Eyespot and take-all of wheat and barley. *In: New techniques in the development of winter wheat*. Nickersons, Grimsby.
- 7.5. GREGORY, P. H. (1960). Outdoor aerobiology. *Endeavour*, **19**, 223-228.
- 7.6. GREGORY, P. H. (1960). Botrytis diseases of narcissus. *Daffodil Tulip Yearb. for 1961*, 112-116.
- 7.7. HARRISON, B. D. (1960). The biology of soil-borne plant viruses. *Advanc. Virus Res.* **7**, 129-159.
- 7.8. KLECZKOWSKI, A. (1960). Photoreactivation in viruses and plants. *3rd int. Congr. Photobiol.*, Copenhagen, 1960.
- 7.9. LAPWOOD, D. H. (1960). Recent developments in breeding for the control of potato blight. *N.A.A.S. Quart Rev.* no. 47, Spring 1960, 93-98.
- 7.10. WATSON, MARION A. (1960). Interaction, or genetic recombination, between potato viruses Y and C. *In: Symposium on "The nature and exploitation of crop plants; resistance to disease"*. London, January 1960.
- 7.11. WATSON, MARION A. (1960). The ways in which plant viruses are transmitted by vectors. *Rep. 7th Commonwealth ent. Conf.* London, 1960.

RESEARCH PAPERS

- 7.12. BAWDEN, F. C. & KLECZKOWSKI, A. (1960). Some effects of ultraviolet radiation on the infection of *Nicotiana glutinosa* leaves by tobacco mosaic virus. *Virology*, **10**, 163-181.

Ultraviolet radiation affects the capacity of *Nicotiana glutinosa* leaves to support the multiplication of tobacco mosaic virus (TMV) more than was assumed by previous workers, and conclusions drawn from experiments in which leaves were irradiated at different intervals after inoculation are of doubtful validity. The effects vary greatly with changes in the physiological state of leaves, and, although exposing irradiated leaves to daylight can repair irradiation damage, photoreactivation does not produce a constant response; depending on the dose of radiation energy and the state of the leaves, photoreactivation may enhance the original capacity, restore it completely or restore it only partially. Rubbing leaves twice can prevent daylight from repairing damage done by radiation to the leaf's capacity.

The response to photoreactivation also depends on the type of inoculum. When leaves are inoculated with intact TMV immediately after irradiation, exposure to daylight increases the number of lesions to the same extent as when irradiated leaves are kept in daylight for some hours before they are inoculated. By contrast, leaves inoculated with infective nucleic acid immediately after irradiation produce no more lesions when kept in the light than when kept in the dark; irradiated leaves kept in the light for some hours before inoculation, however, produce more lesions than comparable leaves kept in darkness. Photoreactivation of the leaf's capacity to support infection takes some time, and it seems that the intact virus particles can survive this time unharmed *in vivo*, whereas the unstable nucleic acid is inactivated. Further evidence for the instability of the nucleic acid came from experiments with irradiated inocula; the nucleic acid was photoreactivated when leaves were exposed to daylight immediately after inoculation, but not when they were kept in darkness for 0.5-1 hour before being exposed to light. Nucleic acid that does not establish infection within an hour of inoculation seems to be destroyed.

- 7.13. BROADBENT, L. (1960). Infectivity of aphids bred on virus-infected cauliflower plants. *Ann. appl. Biol.* **48**, 377-383.

Caged cauliflower plants infected with either cabbage black ring spot virus (CBRSV) or cauliflower mosaic virus (CIMV) were colonised with *Myzus persicae* or *Brevicoryne brassicae*. Winged and wingless aphids that voluntarily flew or walked from these plants were transferred singly to healthy cauliflower or other brassica seedlings to compare their feeding behaviour and ability to transmit the viruses. Wingless aphids settled to probe more readily than winged, and *B. brassicae* was initially more restless than *M. persicae*. CIMV was more readily transmitted than CBRSV by both species, and *B. brassicae* rarely transmitted CBRSV. Wingless aphids transmitted less often than winged ones, and no wingless *B. brassicae* transmitted CBRSV, although they did CIMV. Fewer aphids transmitted CBRSV from old plants than from young ones, but plant age had little effect on CIMV transmission.

- 7.14. BROADBENT, L. & HEATHCOTE, G. D. (1960). Detection of leaf roll in potato tubers. *Plant Path.* **9**.

Some potato plants show no external symptoms during the year in which they become infected with virus. As their tubers will give diseased plants in the next year, a method for deciding whether or not seed tubers are infected would be very useful. Two methods were tested. First, a staining technique was tried, based on the abnormal formation of callose in the phloem sieve tubes of tubers with leaf-roll virus. Second, newly harvested tubers were treated chemically to break their dormancy, and they were grown on the south coast of England during the autumn.

The staining technique was unsatisfactory because only leaf roll is identified and virus Y is often prevalent in some parts of England. The second method shows little promise because of the danger of frost and the slight symptoms shown in the autumn.

- 7.15. BROADBENT, L., HEATHCOTE, G. D., (BROWN, P. H. & WHEELER, G. F.) (1960). Home produced seed potatoes (earlies). 1. Prevention of virus infection by spraying for aphid control. *Exper. Hort.* **3**.

Trials at Efford Experimental Horticulture Station showed that whereas unsprayed stocks of first early potatoes quickly became infected with aphid-transmitted viruses, particularly leaf roll, spraying controlled aphids and limited the spread of viruses *within* the crop. Sprayed stock were retained healthy enough to use as seed for several years. Roguing in addition to spraying further decreased incidence. The thoroughness and correct timing of spraying was important. It should begin at 75% emergence and be repeated at 14-day intervals as long as the plants are actively growing. DDT emulsion is an efficient and economic insecticide used at 2 lb. active ingredient per acre per application.

- 7.16. BROADBENT, L., HEATHCOTE, G. D. & BURT, P. E. (1960). Field trials on the retention of potato stocks in England. *Eur. Potato J.* **3**, 251-262.

Field trials done to supplement replicated small-plot trials showed that the incidence of leaf roll and Y viruses in potato crops remained low for several years in many parts of England when the crops were sprayed with insecticide, and in some parts, where aphids were few, without spraying. Four sprays with DDT emulsion at 2 lb. of active ingredient per acre per application, at intervals of 14 days, starting soon after the plants emerged, were enough to check spread from sources within the crop.

Insecticides did not prevent viruliferous aphids, coming from outside the crop, from infecting sprayed plants. Although many growers could safely keep potato stocks for several years longer than they do now, others could not because virus Y is introduced by aphids from other crops in the same area. Risk from incoming infective aphids will remain until all potato crops are free from virus, but if all infected crops were sprayed with an efficient aphicide before the summer dispersal flight this should greatly decrease the amount of disease introduced into healthy crops.

- 7.17. BURT, P. E., BROADBENT, L. & HEATHCOTE, G. D. (1960). The use of soil insecticides to control potato aphids and virus diseases. *Ann. appl. Biol.* **48**, 580-590.

(For summary see below no. 9.5.)

- 7.18. BUXTON, E. W. (1960). Effects of pea root exudate on the antagonism of some rhizosphere micro-organisms towards *Fusarium oxysporum* f. *pisi*. *J. gen. Microbiol.* **22**, 678-689.

The microbial populations of rhizosphere soil from pea varieties Onward, susceptible to wilt by *Fusarium oxysporum* f. *pisi* race 1, and wilt-resistant Alaska were assessed at six successive plant-growth stages, by the dilution plate technique. The most commonly found rhizosphere organisms were: *Gliocladium roseum*, *Penicillium* spp., bacteria, *Fusarium roseum*, *F. oxysporum*, *F. solani*, *Mortierella* spp., *Rhizopus stolonifer* and *Trichoderma viride*. Root exudate from variety Onward stimulated growth and sporulation of some of the more prevalent 24 of 60 different species among 137 morphologically different isolates of fungi and bacteria. Testing the rhizosphere isolates for their *in vitro* effects on the pathogenic *Fusarium* showed that 15% had no effect, 29% were slightly inhibitory, 42% considerably more and 14% strongly inhibitory. Prominent among the strongest inhibitors were a few bacteria, *Gliocladium roseum* and strains of *F. oxysporum*, the last showing that intraspecific inhibition occurs among the Fusaria.

When 10 of the more prevalent rhizosphere fungi were grown in media containing rhizosphere soil extract, root exudate or both, their ability to inhibit the pathogenic *Fusarium* greatly increased; the most inhibition was obtained with culture filtrates of fungi grown in the presence of both rhizosphere soil extract and root exudate. Morphologically different isolates of *Gliocladium roseum* and *Fusarium oxysporum* inhibited the pathogenic *Fusarium* to different extents, showing that these species contain physiologic strains that could act differentially towards *F. oxysporum* f. *pisi* in the rhizosphere.

The rhizosphere of the wilt-resistant variety Alaska contained no more inhibitory isolates than the rhizosphere of the wilt-susceptible Onward. Although there were more micro-organisms per unit of dry rhizosphere soil of the susceptible variety, the species isolated from the rhizospheres of the susceptible and resistant varieties did not differ qualitatively.

Rhizosphere micro-organisms that were more prevalent up to the time that *Fusarium* invaded the host roots were not prominent among the group most antagonistic towards the *Fusarium*. In addition, there was no correlation between stimulation of rhizosphere organisms by root exudate and their antagonism towards the *Fusarium*. This implies that competition between pathogenic *Fusarium* and the other rhizosphere micro-flora for nutrients in root exudates may be at least as important as overcoming antibiosis in maintaining successful growth of the pathogen near host-root surfaces. Although these results are obtained *in vitro*, they suggest that rhizosphere soil extract and microbial metabolites together deter the growth of *Fusarium oxysporum* f. *pisi* near pea roots, and that the growth-promoting effects of root exudate from the wilt-susceptible pea variety Onward are partially offset by its ability to increase inhibition by some of the other rhizosphere inhabitants.

- 7.19. BUXTON, E. W., (DOLING, D. A.) & (J. D. REYNOLDS) (1960). Additional pea varieties and new selections resistant to *Fusarium* wilt. *Plant Path.* **9**, 54-56.

During 1959 further experiments to find pea varieties that resisted wilt, caused by *Fusarium oxysporum* f. *pisi*, were done in the same way as those in 1958 and earlier (Buxton, Perry, Doling & Reynolds, *Plant Path.* 1959, **8**, 39-45). Two approaches to the problem were made: testing for wilt-resistance in progeny of healthy plants selected from varieties that wilted in 1958, and growing further pea varieties to determine their reactions to wilt. The experiments were at Yaxley, Peterborough, on wilt-infested land used for the 1958 experiments, and at Coggeshall, Essex, on a field that had carried severely wilted crops of peas, varieties British Lion and Clipper, in 1958.

- 7.20. (CADMAN, C. H.,) DIAS, H. F. & HARRISON, B. D. (1960). Sap-transmissible viruses associated with diseases of grape vines in Europe and North America. *Nature, Lond.* **187**, 577-579.

Viruses were transmitted to *Chenopodium amaranticolor*, *Nicotiana glauca* and other herbaceous plants by inoculation of sap from North American, Portuguese, French and Swiss grape vines affected by virus diseases of either the fanleaf type or the yellow mosaic type, but not from normal grape vines of the same varieties. An isolate from a North American grape vine with fanleaf caused typical fanleaf symptoms when transmitted back to grape, but it is uncertain whether the viruses obtained from plants with diseases of the yellow mosaic type are the cause of the yellow mosaic symptoms. Isolates from grape plants with yellow mosaic diseases were less virulent in herbaceous plants than those from plants with fanleaf-type symptoms. *In vitro* properties in *C. amaranticolor* sap of five isolates selected for detailed study were: thermal inactivation point, 58-65°; dilution end-point, $\frac{1}{500}$ - $\frac{1}{10000}$; longevity *in vitro* at 18°, 6-28 days. Serological tests showed that all the isolates tested had antigens in common and polygonal particles of diameter about 30 m μ . The grape viruses also share a few of their antigens with arabis mosaic virus. The distribution of a disease of the fanleaf type in two Portuguese vineyards was correlated with that of the nematode *Xiphinema index*, whereas *X. americanum* was present in all parts of the vineyards.

- 7.21. GIBBS, A. J. (1960). Studies on the importance of wild beet as a source of pathogens for the sugar-beet crop. *Ann. appl. Biol.* **48**, 771-779.

Beet yellows virus, beet mosaic virus, rust (*Uromyces betae* (Pers.) Lév.) and downy mildew (*Peronospora schachtii* Fuckel) were found to be common in wild beet (*Beta vulgaris* S.-sp. *maritima* L.) growing on the foreshores of South Wales and southern England. The virus diseases were more prevalent in south-east England than in the west, rust more in the west than in the east, and downy mildew is equally prevalent in all regions.

Beet yellows is the most commercially important disease and is more common in sugar-beet crops in East Anglia than elsewhere in Great Britain. There was no evidence that beet yellows spread in East Anglia from wild beet to nearby sugar-beet crops during the springs of 1958 or 1959, and *Myzus persicae* Sulz., the principal vector of yellows, was rarely found on wild beet growing on the foreshore.

In glasshouse experiments aphids colonised sugar-beet plants watered with tap water in preference to those watered with sea-water. Daily watering with sea-water made plants unpalatable to aphids within 14 days. Aphids also preferred leaves sprayed with distilled water to those that had been sprayed with sea-water. Salt solutions gave results similar to those obtained with sea-water.

- 7.22. GIBBS, A. J. & GOWER, J. C. (1960). The use of a multiple-transfer method in plant virus transmission studies—some statistical points arising in the analysis of results. *Ann. appl. Biol.* **48**, 75-83.

The frequency of success of attempts to transmit a virus disease from one plant to another has long been used to measure the effects of any of the factors which influence transmission. Samples are taken from the population under test (e.g., vectors, diseased plants, etc.), and usually one sample is tested on each test plant; this is binomial sampling. However, in the procedure we name the "multiple-transfer method" more than one sample may be tested on each test plant. This increases the number of samples tested without increasing the number of test plants used, and errors from heterogeneity in the population under test are therefore lessened. Results from experiments using the multiple-transfer method may be evaluated by using the maximum likelihood estimator. The method is particularly reliable when the proportion of infected samples being studied is small, but can lead to considerable over-estimation when the proportion is high.

- 7.23. HARRISON, B. D. & NIXON, H. L. (1960). Purification and electron microscopy of three soil-borne plant viruses. *Virology*, **12**, 104–117.

Highly infective, purified preparations of tomato black ring, raspberry ringspot and arabis mosaic viruses were obtained by macerating infected *Petunia hybrida* or tobacco leaves in a butanol-chloroform mixture, followed by clarification, differential centrifugation and rate zonal centrifugation in sucrose density gradients. The sedimentation rates of the three viruses relative to that of tobacco mosaic virus were estimated. Electron micrographs of shadowcast mounts of formalin-treated preparations showed that all three viruses have icosahedral particles of average diameters 29–30 m μ . Particles embedded in phosphotungstate often appeared polygonal in outline, but were smaller in diameter than those in shadowed mounts. Some particles of each virus were deeply penetrated by phosphotungstate, but others were not. Infectivity was always associated with the presence of unpenetrated particles, but there was no evidence that the penetrable ones were infective. Particle shape, mode of transmission, properties *in vitro* and behaviour in plants all suggest that these viruses should be placed in the same general group in any classification of plant viruses.

- 7.24. HIRST, J. M. & STEDMAN, O. J. (1960). The epidemiology of *Phytophthora infestans*. I. Climate, ecoclimate and the phenology of disease outbreak. *Ann. appl. Biol.* **48**, 471–488.

Temperature and relative humidity of air within and above potato crops were recorded throughout the growing seasons of 1951–58, with wet- and dry-bulb mercury-in-steel thermographs. Diurnal periodicity curves of successive weeks showed that conditions within the crop changed, relative to those above, as the crop grew. When much bare ground was exposed the air within the crop was warmer and less humid at midday than at 4 feet above ground, particularly in dry and sunny weather. The growth of foliage and the amount of sunshine and rain determined how quickly this pattern was replaced by one with smaller temperature differences and crop humidity slightly in excess of that above it, at all times of day. Rain on crops with dense foliage almost completely eliminated temperature differences and gave relative humidities over 90% that persisted in the crop for a larger proportion of each day than in the screen. Finally, as the disease defoliated the crop and again exposed the soil, the relationship partly reverted to that early in the season.

Above the crops, curves of the number of hours per day with relative humidity not less than 90% rose and fell with the passing of wet spells. At first this was also true within crops, but when foliage was dense the rise in relative humidity after rain often persisted through intervals of dry weather. Such conditions usually preceded the appearance of potato blight in epidemic proportions by 1–3 weeks. It is difficult to account for the regularity of blight outbreaks by seasonal climatic changes, and although many factors are probably involved, changes in ecoclimate seem important. When knowledge about the response of *Phytophthora infestans* is related to the meteorological observations and to the dates of blight outbreak the growth of potato crops seems often to be self-destructive, because it progressively modifies the immediate environment to favour the spread of the crop's most destructive pathogen.

- 7.25. HIRST, J. M. & STEDMAN, O. J. (1960). The epidemiology of *Phytophthora infestans*. II. The source of inoculum. *Ann. appl. Biol.* **48**, 489–517.

Of 3,260 blighted tubers planted as seed in 5 successive years (1954–58), 21 produced stems invaded from below ground by *Phytophthora infestans* (0.79 and 0.52% respectively of those infected artificially and naturally). Only in 1955 was no stem found to be invaded, in every other year they started epidemics in experimental plots. On average, the first stem lesions were found 62 days after planting and 38 days before blight outbreak became general in the district.

There was evidence of two patterns of dispersal for *P. infestans*. Distant spread was probably by air-borne sporangia, but that near to the initial sources probably resulted from sporangia transported in water. The effects of initial

sources of infection on the date when the disease became general could not be traced for more than a few hundred yards. Blight often reached crops remote from the experiments at the same time as it infected every plant within them; this often happened during the weather which elicited disease forecasts.

Under certain conditions of soil moisture *P. infestans* from artificially infected tubers planted as seed seemed able to pass through the soil to infect leaves near it and to start epidemics without invading stems from below ground. Attacks originating in this way developed similarly to those started by invaded stems, but their importance and the conditions limiting their occurrence have yet to be determined.

- 7.26. KASSANIS, B. (1959). Comparison of the early stages of infection by tobacco mosaic virus and its nucleic acid. *J. gen. Microbiol.* **20**, 704-711.

The early events in the infection of tobacco and *Nicotiana glutinosa* by tobacco mosaic virus occur sooner when the inoculum is the nucleic acid of the virus than the whole virus. In plants at 28° newly formed virus becomes detectable between 6 and 8 hours after inoculation with the nucleic acid and after 8-10 hours with whole virus. Although the latent period is lengthened by lowering temperature, the difference between the lengths of the latent periods given by the two inocula is little changed. Infective centres initiated by nucleic acid also become resistant to hot-water treatment (a 30-second dip in water at 50°) about 2-4 hours sooner than do those initiated by whole virus.

Exposure of inoculated plants to 37° decreases the number of lesions produced by the nucleic acid much more than by whole virus; resistance to this treatment develops from 30 to 120 minutes after inoculation with the nucleic acid, depending on the temperature at which the plants are kept.

- 7.27. KASSANIS, B. (1960). Potato virus M and paracrinkle. *Nature, Lond.* **188**, 688.

A short account is given of the different strains of potato paracrinkle virus found in commercial stocks of the potato variety King Edward; some of the strains are transmitted by aphids.

- 7.28. KASSANIS, B. & NIXON, H. L. (1960). Activation of one plant virus by another. *Nature, Lond.* **187**, 713-714.

This is a preliminary note on the relationship between the small and large virus particles present in the "Rothamsted culture" of tobacco necrosis virus.

- 7.29. MULLIGAN, T. E. (1960). The transmission by mites, host-range and properties of ryegrass mosaic virus. *Ann. appl. Biol.* **48**, 575-579.

A virus that causes chlorotic streaks on ryegrass leaves was transmitted by the eriophyid mite *Abacarus hystrix* (Nalepa). Virus-free mites acquired the virus in 2 hours feeding on infected ryegrass, and the proportion that became infective increased with increased feeding time up to 12 hours; vectors lost infectivity within 24 hours of leaving the infected leaves. All instars of *A. hystrix* transmitted the virus.

The virus was transmitted by manual inoculation of sap to other species of Gramineae, including oats, rice, cocksfoot and meadow fescue, but none of these hosts seemed to contain as much virus as ryegrass; their saps did not precipitate specifically with antiserum prepared against the virus in ryegrass, whereas sap from infected ryegrass precipitated up to a dilution of $\frac{1}{32}$. Infective sap of S.22 Italian ryegrass contained flexuous rod-shaped particles; the dilution end-point of the virus was about 1 in 1000; the virus was inactivated when held for 10 minutes at 60° and most of its infectivity was lost after 24 hours at room temperature.

T

- 7.30. NIXON, H. L. & GIBBS, A. J. (1960). Electron microscope observations on the structure of turnip yellow mosaic virus. *J. molec. Biol.* **2**, 197-200.

Electron micrographs of turnip yellow mosaic virus particles prepared by the negative staining technique show clearly defined internal structure which indicates that the protein shell of this virus is constructed of 32 sub-units in an icosahedral arrangement. The structure inferred from the electron micrographs satisfies the X-ray data and contains sub-units in two structurally distinct sites.

- 7.31. SINHA, R. C. (1960). Comparison of the ability of nymph and adult *Delphacodes pellucida* Fabricius, to transmit European wheat striate mosaic virus. *Virology*, **10**, 344-352.

The ability of *Delphacodes pellucida* Fabricius to transmit European wheat striate mosaic virus to progeny insects and to plants depends on the age at which they acquire virus from diseased plants, and is greater with nymphs than with adults. Infective progeny and eggs that died were produced only by infective mothers that had fed on diseased plants when nymphs. There may be a critical time comparatively early in the development of the ovaries before which the virus must be established in them to be transmitted to progeny insects.

Adult plant-hoppers were rendered infective by puncturing their anterior abdomens with a fine needle immediately before or after feeding on diseased plants. Puncturing the abdomen a week after acquiring the virus or puncturing the thorax at any time did not make them infective. Evidently wheat striate mosaic virus must pass through the gut wall of *D. pellucida* for the insect to become infective, and the permeability of the gut wall to virus presumably decreases with increasing age of insect.

- 7.32. SINHA, R. C. (1960). Red clover mottle virus. *Ann. appl. Biol.* **48**, 742-748.

A virus, provisionally named red clover mottle virus (RCMV), isolated from red clover plants in England seems distinct from any previously described. It was transmitted by mechanical inoculation of sap to many legumes and to *Gomphrena globosa* L., but it was not transmitted by six aphid species, through soil or through seeds.

RCMV is inactivated in 10 minutes between 60 and 63°, and in 8 days at 18°, but survives for long periods at -20°; sap was not infective when diluted more than $\frac{1}{10000}$. The virus is soluble in the pH range (4-7), in which it is stable. It was precipitated without inactivation by 50% saturated ammonium sulphate solution, but it was inactivated by ethanol or acetone. Partially purified preparations contained polygonal particles about 28 m μ in diameter. Serological tests showed no antigens in common with broad bean mottle, true broad bean mosaic or lucerne mosaic viruses.

- 7.33. SINHA, R. C. (1960). Some effects of temperature and of virus inhibitors on infection of French-bean leaves by red clover mottle virus. *Ann. appl. Biol.* **48**, 749-755.

Keeping French-bean plants before inoculation at 36°, 32° or 28° for 1-2 days increased their susceptibility to infection with red clover mottle virus, but longer exposures to 36° and 32° decreased susceptibility. Susceptibility increased most rapidly at 36°. The number of infections was unaffected by changes in post-inoculation temperatures between 12° and 24°, but decreased above 24°. The rate virus multiplied increased with increase of temperature up to 28°, but the maximum virus concentrations reached at 18°, 24° and 28° were very similar and above the maximum reached at 30°.

Thiouracil inhibited infection slightly, but neither it nor azoguanine affected the multiplication of red clover mottle virus in French bean. Trichothecin inhibited infection and interfered with virus accumulation. Inhibition of infection was associated with macroscopic injury to the leaves, and washing leaves up to 1 hour after inoculation prevented both inhibition and leaf damage. Virus multiplication was not resumed when leaves were transferred from trichothecin solutions to water.

- 7.34. WATSON, M. A. (1960). Evidence for interaction or genetic recombination between potato viruses Y and C in infected plants. *Virology*, **10**, 211-232.

When potato virus Y (PVY), which is aphid-transmitted, and a related virus, potato virus C (PVC), which is not aphid-transmitted, were jointly inoculated to *Nicotiana glutinosa* plants, mixed isolates, transmitted by aphids from systemically infected leaves had some of the properties of both.

Like PVY, they were transmitted by *Myzus persicae*, but unlike PVY, they caused black necrotic lesions on inoculated leaves of Majestic, President and Craig's Snow-White potatoes (*Solanum tuberosum* L.). Like PVY and unlike PVC, they caused systemic infection when manually inoculated to the potato varieties, but the symptoms that developed resembled those caused by PVC when it is transmitted to the same varieties by grafting. Many isolates from local lesions caused by the mixed virus isolates on potato were like PVC, and few resembled PVY. Isolates from systemically infected parts of potato less often gave symptoms like those caused by PVC, and many gave mild mottle with no necrosis.

Three PVC-like viruses that resemble the isolates from mixed infection are: PVC^a, and aphid-transmissible PVC-like virus described previously (Watson, 1956); PVC^{nlab}, found naturally occurring in International Kidney potatoes in Jersey, and a virus from India found in *Solanum jasminoides* (Badami and Kassanis, 1959). These viruses do not usually invade the potato varieties systemically, but occasionally yield isolates that do so. The symptoms when they do invade resemble those caused by the isolates from mixed infections in *N. glutinosa*, and often appear to be genetically unstable, although the viruses from which they were derived are either stable in potato or, as with PVC^a, revert to a form even more like PVC.

The nature of the interaction between PVC and PVY is unknown, but a likely explanation is that particles are formed that carry genetic determinants from both viruses.

- 7.35. WATSON, M. A. (1960). Carrot motley dwarf virus. *Plant Path.* **9**, 133-134.

A virus disease of carrots that causes loss of yield in commercial crops is probably carrot motley dwarf described from Australia by Stubbs (1948, 1952). The vector is the willow-carrot aphid *Cavariella aegopodiae*, which migrates in great numbers during May or June. Carrot motley dwarf is a persistent virus, the aphids take several hours to acquire and transmit it, but remain infective for many days. In 1959 carrots at Woburn, Beds, were almost 100% infected before the end of May.

- 7.36. WATSON, M. A. & MULLIGAN, T. (1960). Comparison of two barley yellow-dwarf viruses in glasshouse and field experiments. *Ann. appl. Biol.* **48**, 559-574.

Comparisons were made of the host ranges, interactions in infected plants and effects on yields of cereals of two isolates of barley yellow-dwarf virus, one avirulent, RV, obtained from Rothamsted farm, and the other virulent, KV, obtained from Kent. They resembled each other and the American yellow-dwarf viruses in their ability to infect wild grasses, but differences were found when the infection tests were made using inbred lines of the same grass species. KV infected one variety each of rice, rye and maize, and caused symptoms in each.

When plants were first infected with RV and later, when symptoms had fully developed, with KV, they suffered the same loss of yield from KV as did plants infected for the same length of time with KV alone. Therefore plants infected with RV were not protected against infection with KV. Similarly, aphids (*Rhopalosiphum padi* L.) fed first on sources of RV and then on KV, transmitted mainly KV, so there was no evidence of protection in the insect vectors.

Effects on yield of cereals were related to the time of appearance and intensity of symptoms. The effect of RV was less than that of KV and varied more.

- 7.37. WATSON, M. A. & MULLIGAN, T. (1960). The manner of transmission of some barley yellow-dwarf viruses by different aphid species. *Ann. appl. Biol.* **48**, 711–720.

Some barley yellow dwarf (BYD) viruses isolated from cereal crops in Great Britain were transmitted by *Rhopalosiphum padi* L. and others were not. *Sitobium fragariae* (Walker), *S. avenae* (Fabricius) and *Metopolophium dirhodum* (Walker) all transmitted viruses of both types, but they usually transmitted those of which *R. padi* was a vector less readily than did *R. padi*. The transmissibility of a virus by a given aphid species was not affected by transmission with another, less efficient, vector species. *Myzus circumflexus* (Buckt.) and *Rhopalosiphum maidis* (Fitch) transmitted the few viruses with which they were tested.

A few *R. padi* acquired virus from infected leaves during 30 minutes feeding and inoculated healthy seedlings during 15 minutes feeding, but the minimum total time taken to acquire and transmit was 10 hours, and 32 hours were needed for about half the aphids that were able to acquire and transmit virus to do so. This may indicate the existence of a short latent period of the virus in the vector, although the evidence is not conclusive. The times spent on infected plants influenced the results more than those spent on healthy ones; many transmissions occurred with short feeding times on healthy plants so long as the time spent on infected leaves was long, but the reverse was not true. Nymphs of *R. padi* that moulted after they left infected plants on which they fed long enough to become infective, infected slightly fewer plants than adults fed for the same times.

Nematology Department

GENERAL PAPERS

- 8.1. GOODEY, J. B. (1960). Gall-forming nematodes of grasses in Britain. *J. Sports Turf Res. Inst.* **10**, 54–60.
- 8.2. HESLING, J. J. (1961). Laboratory note. *Nematologica*, **5**, 322.
- 8.3. HESLING, J. J. (1961). Chrysanthemum eelworm. *Gdnrs' Chron.* **149**. (In the press.)
- 8.4. JONES, F. G. W. (1959). Resistance breaking biotypes of potato-root eelworm. *Proc. IVth int. Congr. Crop Protection Hamburg 1957*, **1**, 591–594.
- 8.5. JONES, F. G. W. (1960). Plant parasitic nematodes. *Advanc. Sci.* **17**, 174–180.
- 8.6. JONES, F. G. W. (1961). Some observations and reflections on host finding by plant nematodes. *Meded. LandbHoogesch. Gent*, **25**, 1009–1024.
- 8.7. JONES, F. G. W. (1960). Nematode injury to crops. *Proc. Nutr. Soc.* **20**. (In the press.)
- 8.8. WALLACE, H. R. (1960). Recent observations on chrysanthemum eelworm. *Quart. Bull. nat. Chrysanth. Soc.* no. **43**, 10–13.
- 8.9. WALLACE, H. R. (1961). Chrysanthemum eelworm. *Year Book nat. Chrysanth. Soc.* 1960/61, 107–123.
- 8.10. WALLACE, H. R. (1961). The bionomics of the free-living stages of zoo-parasitic and phyto-parasitic nematodes—a critical survey. *Helminth. Abstr.* **30**, 1–22.
- 8.11. WINSLOW, R. D. (1960). Nematode ecology. *In: Nematology*, ed. J. N. Sasser & W. R. Jenkins. Chapel Hill, U.S.A., Univ. N. Carolina Press, pp. 341–415.

RESEARCH PAPERS

- 8.12. CLARK, W. C. (1960). The oesophago-intestinal junction in the Mononchidae (Enoplida: Nematoda). *Nematologica*, **5**, 178-183.

Some morphological features of the oesophago-intestinal junction of the Mononchidae often disappear soon after fixation, especially the funnel-shaped valve which is surrounded by the sphincter muscle. Published accounts of this region do not agree with the morphology of live nematodes. The oesophago-intestinal valves of the Mononchidae are of two types: 1. the *tuberculate* type, which is characterised by the presence of three conspicuous, hollow tubercles on the posterior end of the oesophageal lining near the funnel-shaped valve, and 2. the *non-tuberculate* type, in which the tubercles are absent and the oesophageal lining becomes narrower near the posterior end. The *tuberculate* type of valve is found in *Anatonchus*, *Iotonchus* and *Miconchus*; and the non-tuberculate type in *Mononchus*, *Prionchulus*, *Mylonchulus* and *Cobbonchus*.

Mononchus mauritianus Williams, 1958, is transferred to the genus *Cobbonchus* Andrassy.

- 8.13. CLARK, W. C. (1960). Redescription of *Mononchus truncatus* Bastian, *M. papillatus* Bastian and *Prionchulus muscorum* (Dujardin). *Nematologica*, **5**, 184-198.

Mononchus truncatus Bastian (= *M. macrostoma* Bastian) and *M. papillatus* Bastian are redescribed from topotypic material, and neotypes have been designated. *Prionchulus muscorum* (Dujardin, 1945) Cobb, 1916, is redescribed from British populations. The differences between *M. papillatus* and *P. muscorum* are tabulated.

- 8.14. CLARK, W. C. (1960). The Mononchidae (Enoplida: Nematoda) of New Zealand. 1. The genera *Mononchus* Bastian and *Prionchulus* (Cobb). *Nematologica*, **5**, 199-214.

Mononchus composticola, *M. mesadenus*, and *M. propapillatus* n. spp. are described, and *Prionchulus muscorum* (Dujardin) is recorded from New Zealand. *M. campbelli* Allgén, 1929, is regarded as a species *inquirenda*. *M. composticola* and *M. mesadenus* are allied to *M. gerlachei* de Man, 1904, and *M. major* Cobb, 1893, from which species they may be separated by the key provided.

- 8.15. CLARK, W. C. (1961). The Mononchidae (Enoplida: Nematoda) of New Zealand. 2. The genus *Iotonchus* (Cobb) Altherr. *Nematologica*, **5**, 260-274.

Iotonchus (Cobb, 1916) Altherr, 1952, is redefined, and is distinguished from *Mononchus* Bastian by the tuberculate oesophago-intestinal junction, the dorsal tooth, which lies wholly or mainly in the posterior half of the stoma, and the broad base of the stoma. *I. jairi* (Lordello, 1959) n. comb. and *I. tenuidentatus* (Kreis, 1924) n. comb. are transferred to the genus from *Mononchus*.

I. basidontus n. sp. differs from *I. gymnolaimus* and *I. consimilis* in the possession of paired ovaries. *I. maragnus* n. sp. is characterised by the possession of a very long filiform tail ($c = 2.3-2.9$) and the anterior position of the vulva ($V = 36-39$). *I. ophiocercus* n. sp. is the only long-tailed member of the genus with the tooth apex near the middle of the stoma. *I. percivali* is the largest species in the genus ($L = 6$ mm.), has a long tail ($c = 3.8-4.1$), a median vulva and paired ovaries. *I. parazschokkei* (Allgén, 1929) is redescribed.

- 8.16. CLARK, W. C. (1961). The Mononchidae (Enoplida: Nematoda) of New Zealand. 3. A review of the genus *Cobbonchus* Andrassy, with descriptions of new species. *Nematologica*, **5**, 275-284.

The genus *Cobbonchus* Andrassy, 1958, is redefined and new descriptions of *C. palustris* (Cobb), *C. radiatus* (Cobb) and *C. teres* (Cobb) have been compiled

from Cobb (1917) and some of Cobb's unpublished figures. *C. mauritanus* (Williams) has been redescribed. *C. chauliodus* n. sp. differs from others in its large size, massive dorsal tooth and single prodelphic ovary. *C. pounamua* n. sp. is distinguished from *C. palustris* on head shape, the pointed stoma base and the greater number of cephalic papillae.

- 8.17. CLARK, W. C. (1961). The Mononchidae (Enoplida: Nematoda) of New Zealand. 4. The genus *Mylonchulus* (Cobb) Pennak. *Nematologica*, **6**, 1-6.

Mylonchulus arenicolus and *M. ubis* n. spp. are described from New Zealand soils.

- 8.18. CLARK, W. C. (1961). A revised classification of the Enoplida Nematoda. *N.Z. J. Sci.* **4**. (In the press.)

The order Enoplida is re-classified into seven sub-orders mainly on the basis of the arrangement of the oesophageal glands and their ducts. The sub-orders recognised are Enoplina, Alaimina n. sub-order, Dorylaimina, Trichosyringina (composed of the Mermithoidea and Trichuroidea) and Dioctophymatina. The Mononchidae are removed from the Tripyloidea, and with the Bathyodontidae n. fam. (type genus *Bathyodontus* Fielding, 1950) comprise the Mononchoidea n. superfamily within the Dorylaimina. The Belondiridae and Nygolaimidae have been redefined, *Nygellus* Thorne, 1939, is transferred from the former to the latter and the Nygolaimellinae n. subfam. (type genus *Nygolaimellus* Loos, 1949) erected. The Campydorinae are removed from the Leptonchidae and elevated to family rank. The Trichodorinae are given family rank, and with the Diphtherophoridae form the Diphtherophoroidea within the Dorylaimina. In the Trichuroidea four families and four subfamilies are recognised. Skrjabin & Schikhobalova's (1954) proposal to unite the Trichuroidea with the Dioctophymatina is rejected on the grounds of morphology and life history. The life history of *Dioctophyme renale* indicates a relationship between the Dioctophymatina and the Gordiacea. The name *Octonchus* nom. nov. is proposed pro *Polydontus* Schultz, 1932 preocc. nec. *Polydontus* Blainville, 1926, a mollusc.

- 8.19. FENWICK, D. W. (1961). Estimation of field populations of cyst-forming nematodes of the genus *Heterodera*. *J. Helminth.*, Leiper Supplement, 63-76.

Fields infested with cyst-forming nematodes differ greatly from one another in the level of infestation and in the uniformity of its distribution. Composite samples taken from such fields, for which general estimates of the population level are required, should be made up of from 25 to 100 borings. The increase in precision obtained by taking more than 100 borings is rarely justified. Even when more borings are taken and the quantity of soil used for extraction in the laboratory is increased to give large cyst counts, errors remain high. The accuracy of estimates based on composite samples is variable and cannot be forecast in advance for a given field. If it is desired to work at a predetermined level of accuracy preliminary samples should be taken to estimate the heterogeneity of the population. Final sampling procedure should be based on this estimate.

- 8.20. FRANKLIN, M. T. (1961). A British root-knot nematode, *Meloidogyne artiellia* n. sp. *J. Helminth.*, Leiper Supplement, 85-92.

A new root-knot nematode was found by a member of the N.A.A.S. on the roots of oats and brassicas from Norfolk. This is described and named. It is the first species of *Meloidogyne* to be described initially in Britain.

- 8.21. GOODEY, J. B. (1960). The classification of the Aphelenchoidea Fuchs, 1937. *Nematologica*, **5**, 111-126.

The Aphelenchoidea are considered to be composed as follows: Aphelenchidae—*Aphelenchus*. Aphelenchoididae—*Aphelenchoides*, *Seinura*, *Megadorus*, *Tylaphelenchus*, *Laimaphelenchus*, *Bursaphelenchus*, *Cryptaphelenchus*,

Cryptaphelenchoides, *Ektaphelenchus*, *Parasitaphelenchus*, *Peraphelenchus* and *Entaphelenchus*. Paraphelenchidae—*Paraphelenchus* and *Metaphelenchus*. Anomyctidae—*Anomyctus*. Sphaerulariidae—*Sphaerularia*, *Tripius*, *Proactonema* and *Scatonema*.

- 8.22. GOODEY, J. B. (1960). Observations on the effects of the parasitic nematodes *Ditylenchus myceliophagus*, *Aphelenchoides composticola* and *Paraphelenchus myceliophthorus* on the growth and cropping of mushrooms. *Ann. appl. Biol.* **48**, 655–664.

The parasitic nematodes *Ditylenchus myceliophagus*, *Aphelenchoides composticola* and *Paraphelenchus myceliophthorus* severely damage mushroom mycelium, and in great numbers decrease or even prevent cropping. The relationships between fluctuation of nematode population, state of the mycelium, duration of cropping and the yield of mushrooms is illustrated by figures.

- 8.23. GOODEY, J. B. (1960). *Rhadinaphelenchus cocophilus* (Cobb, 1919) n. comb., the nematode associated with "Red-Ring" disease of coconut. *Nematologica*, **5**, 98–102.

Aphelenchoides cocophilus is placed in a new genus as *Rhadinaphelenchus cocophilus* (Cobb, 1919) n. comb. and is redescribed from fresh material. The nematode is exceedingly long and narrow ($a \approx 100$), very lithe in water and is characterised by a flap-like terminal bursa in the male and vulval flap in the female.

- 8.24. GOODEY, J. B. (1961). The nature of the spear guiding apparatus in Dorylaimoidea. *J. Helminth.*, Leiper supplement, 101–106.

The spear guiding apparatus is a sheath fused anteriorly and medially to the stoma wall, and basally round the junction of spear and spear extension. The fixed anterior ring is what is seen when specimens are said to have a single ring. As the spear is moved forwards the sheath evaginates, giving the appearance of an apparently double ring. These concepts are applicable to *Nygolaimus*, where the spear is mural, and also to *Aporcelaimus*, which has a plicated, funnel-shaped anterior end to the sheath.

- 8.25. GOODEY, J. B., PEACOCK, F. C. & PITCHER, R. S. (1960). A redescription of *Xiphinema diversicaudatum* (Micoletzky, 1923 and 1927) Thorne, 1939 and observations on its larval stages. *Nematologica*, **5**, 127–135.

The figures and description of *Xiphinema diversicaudatum* of Thorne (1939) appear not to agree with the originals of Micoletzky (1923 and 1927). The species is redescribed from numerous specimens which agree well with the originals. Study showed the range of variation in tail form, the number of caudal papillae, the number of subventral papillae in the male, the variation in length of the guiding sheath of the spear compared with the spear position and the range of form shown by the different larval stages.

- 8.26. GOODEY, J. B. & SEINHORST, J. W. (1960). Further observations and comments on the identity of *Rotylenchus robustus* (de Man, 1876) Filipjev, 1934, with a description of a proposed neotype and a new definition of *Rotylenchus goodeyi*. *Nematologica*, **5**, 136–148.

The authors do not agree with the contention of Loof and Oostenbrink (1958) that *Rotylenchus robustus* (de Man, 1876) and *Hoplolaimus uniformis* Thorne, 1949, are the same species.

Under the International Rules of Zoological Nomenclature *Tylenchus robustus* de Man, 1876, is the type of the genus *Rotylenchus* Filipjev, 1936, and Filipjev's citation of *Tylenchus robustus* de Man, 1880, has no other meaning nomenclatorially than *T. robustus* de Man, 1876.

T. robustus as described by de Man in 1876 differs in several ways (body length, spear length, form of tail and habitat) from *Hoplolaimus uniformis*, and thus is not the same species.

Several specimens have been collected from the type locality of *T. robustus* de Man, 1876 (Clayey meadow soil near Leiden), which agree closely with de Man's description of 1876 (e.g., body length, spear length and form of tail) and from these a neotype has been described.

Anguillulina robusta of T. Goodey, 1932, is considered to be the same as *Rotylenchus robustus* (de Man, 1876). *Anguillulina robusta* of T. Goodey, 1940 and 1951, is not identical with *R. robustus* (de Man), 1876, and remains *Rotylenchus goodeyi* Loof & Oostenbrink, 1958.

R. robustus of Thorne, 1949, is identical neither with *R. robustus* (de Man, 1876) nor with *R. goodeyi* Loof & Oostenbrink.

- 8.27. GREET, D. N. & WALLACE, H. R. (1961). Diagnosis of attacks of *Aphelenchoides ritzemabosi* in chrysanthemums. *Plant Path.* **10**. (In the press.)

Leaves of some chrysanthemum varieties do not show clear interveinal discoloration. Orange Peach Blossom, Amy Shoesmith, Kathleen Doward and Delightful, for example, show interveinal symptoms only in the initial stages of infestation, the affected leaf sectors later become black with a yellow border, and the discoloration is not always limited by the veins. Only varieties resistant to eelworm behave in this manner.

- 8.28. HESLING, J. J. (1961). *Heterodera rostochiensis* Woll. 1923 on *Solanum demissium*—a population study. *Ann. appl. Biol.* **49**. (In the press.)

Cysts of *H. rostochiensis* in three different size grades were used at six different inoculum levels on *S. demissium*. Cyst numbers were adjusted so that the infestation levels (eggs/g. soil) were the same in each series at any one inoculum level: thus, the inoculum was dispersed within many small cysts, several medium cysts or few large ones. The different dispersions had little effect on the final eelworm population. Estimation of total egg content and hatchable, larval content of new cysts, also graded according to size, showed that neither size grade of the cysts inoculated nor the level of infestation had any effect on the egg content or hatchability of the new cysts. Percentage hatch appeared to decline with increase in cyst size; hatching variability was not usefully decreased by using graded new cysts for hatching tests. The smallest new cysts (<0.295 mm.) contained an average of 64 eggs; such cysts are easily overlooked in soil samples.

- 8.29. HESLING, J. J. (1961). Technical problems in the routine, hot-water treatment of chrysanthemum stools against chrysanthemum eelworm *Aphelenchoides ritzemabosi*. *Plant Path.* **10**. (In the press.)

An experimental bath was constructed for treating chrysanthemum stools in water at 46° for 5 minutes. An input power of at least 350 watts per gallon of water was required to regain a temperature drop of 0.5° in half a minute. If the ratio of stools to gallons of water exceeded 1:1 the temperature drop was more than 0.5°. Unless the water was circulated actively and the stools agitated during treatment there were temperature variations in the bath. Treatment of large numbers of stools on a commercial scale seems impracticable.

- 8.30. HESLING, J. J. & WALLACE, H. R. (1961). Observations on the biology of chrysanthemum eelworm, *Aphelenchoides ritzemabosi* (Schwartz) Steiner in florists' chrysanthemum. I. Spread of eelworm infestation. *Ann. appl. Biol.* **49**, 195–203.

A study of the mobility of chrysanthemum eelworm in sand and in a clay soil indicated that it behaves like other eelworm species so far examined. The lateral spread of eelworm in chrysanthemum plots in a nursery did not exceed about 30 inches in the dry season of 1959. The number of infested plants rose sharply with the onset of damp weather in September. Laboratory

experiments showed that the eelworms were more active under humid conditions. Eelworms may invade a leaf within 15–30 minutes after their introduction to it. Eelworms inoculated into clean soil containing uninfested plants produced symptoms on the plants after 18 days, but 26 days after inoculation no eelworms could be detected in the soil. The eelworms disappear in moist fallow soil, and attempts to infest plants with eelworms from heavily infested soil stored over winter failed. Examination of stools during winter showed that many eelworms were present in the green tissues, and it was concluded that infestation from eelworms which persist in soil over winter is slight and that the main source of the pest is the chrysanthemum stool.

- 8.31. HESLING, J. J. & WALLACE, H. R. (1961). Observations on the biology of chrysanthemum eelworm, *Aphelenchoides ritzemabosi* (Schwartz) Steiner in florists' chrysanthemum. II. Symptoms of eelworm infestation. *Ann. appl. Biol.* **49**, 204–209.

Eelworm damage to chrysanthemum leaf tissue was studied by staining leaf-sections. The earliest effect of the eelworm is the appearance of a brown substance inside the leaf-cells, the browning extends and chloroplasts become fewer. Ultimately the cell walls break down and large spaces appear in the leaf. Finally, the epidermis disintegrates and the brown substance is found on all cell walls. Collenchyma around main veins does not break down until the final stage of the disease.

Cuttings of 13 chrysanthemum varieties were artificially infested with about 110 eelworms. Ensuing symptoms were leaf blotch, stunting, blindness, browning of stem and leaf petiole, leaf distortion, leaf scars ("feeding areas") and puffy, blistered and puckered leaves. Infested cuttings which showed severe symptoms produced side-shoots which seemed healthy, but these became badly damaged later in the season. In young leaves the eelworms were often unable to penetrate farther than the substomatal space.

- 8.32. HESLING, J. J. & WALLACE, H. R. (1961). Susceptibility of varieties of chrysanthemum to infestation by *Aphelenchoides ritzemabosi* (Schwartz), *Nematologica*, **5**, 297–302.

Cuttings from 13 chrysanthemum varieties were artificially infested with 110 *Aphelenchoides ritzemabosi*. Most of the cuttings in all varieties eventually showed leaf browning or distortion or blindness. Some varieties had distinctive syndromes of infestation, but there was no difference in susceptibility. Mature plants of different varieties, however, differed greatly in susceptibility. Susceptibility was not determined by stomatal size or frequency, density of epidermal hairs on leaves or stems, size of mesophyll air spaces or thickness of leaf-cell walls.

- 8.33. HESLING, J. J. & WALLACE, H. R. (1961). Observations on the susceptibility of chrysanthemum varieties infested at two different times with chrysanthemum eelworm, *Aphelenchoides ritzemabosi*. *Nematologica*, **6**, 64–68.

The susceptibilities of different varieties of chrysanthemum to *Aphelenchoides ritzemabosi* assessed from a field experiment in 1959 were confirmed by repetition of the experiments at two different sites in 1960 when there was more rain. Many plants infested in March were later destroyed by eelworm, whereas infestations in August had no effect on the crop of blooms, although eelworm symptoms were present. When resistant varieties were infested in August symptoms did not spread because the infested leaves were killed before the eelworms could multiply and move. Many cuttings of resistant varieties, which are hypersensitive to eelworm attack, were killed.

- 8.34. SHEPHERD, A. M. (1960). A study of the apparent decay of eggs within cysts of *Heterodera schachtii* Schmidt and *H. göttingiana* Liebscher, and of free larvae in soil. *Nematologica*, **5**, 103–110.

In batches of randomly selected cysts estimates of total cyst contents based on the sum of larval emergence and residual egg count sometimes show large differences. These differences are greatest where the rates of emergence

differ most, suggesting that eggs may decay within cysts when larvae do not emerge early in the experiment. However, experiments with cysts of *Heterodera schachtii* kept in water for 2 months, and with cysts of *H. göttingiana* and *H. schachtii* kept in soil at different moisture contents, gave no evidence that many eggs are lost from cysts in this way. Usually most of the loss of cyst contents in soil can be attributed to larval emergence. The microflora present may cause occasional epidemics, especially under the conditions of hatching tests.

By contrast, larvae of *H. schachtii* rapidly decline in number in soil with a moisture content corresponding to field capacity, in the absence of a host plant. The larvae are very sensitive to soil conditions, which largely determine the rate at which they succumb.

- 8.35. WALLACE, H. R. (1961). The nature of resistance in chrysanthemum varieties to *Aphelenchoides ritzemabosi*. *Nematologica*, **6**, 49–58.

Leaves of resistant varieties of chrysanthemums brown quickly when infested with *A. ritzemabosi*. In such leaves eelworms do not multiply, so the infestation is isolated and does not spread. Observations on artificially infested plants in the field support this hypothesis of a hypersensitivity type of resistance. Aerated extracts of leaves of resistant and susceptible varieties brown at the same rate and have similar contents of polyphenols and phenol oxidase. Infested leaves of resistant and susceptible varieties brown at different rates because the gravid females move about freely in leaves of resistant varieties, piercing hundreds of cells which subsequently turn brown. In susceptible varieties the females do not move, pierce few cells and lay many eggs. Although 0.01M solutions of chlorogenic acid and quinic acid and a saturated solution of caffeic acid inhibit movement and invasion, no such effects were observed in the infested leaf, and egg laying was not affected.

- 8.36. WALLACE, H. R. (1961). Observations on the behaviour of *Aphelenchoides ritzemabosi* in chrysanthemum leaves. *Nematologica*, **5**, 315–321.

The length of life-cycle of *Aphelenchoides ritzemabosi* is about 10–13 days. Each female lays about 25–35 eggs in compact groups. The eggs take 3–4 days to hatch and the larvae 9–10 days to reach maturity. Fertilisation and egg laying occur chiefly at the boundary between the discoloured and green portions of the leaf. The amount of free water inside the infested leaf is determined by weather; eelworm activity in the leaf is, consequently, mainly confined to periods when there is rain or heavy mists. Early stages of chrysanthemum eelworm are more susceptible to desiccation than late stages. 95% of late stage larvae and adults emerge from leaves immersed in water for 2 days, compared with 12% of early stage larvae. Few small larvae invade leaves or migrate up the plant. Adults, unlike larvae, can swim because they generate greater propulsive forces. Adults and possibly fourth-stage larvae spread infestations.

- 8.37. WALLACE, H. R. (1961). Browning of chrysanthemum leaves infested with *Aphelenchoides ritzemabosi*. *Nematologica*, **6**. (In the press.)

The rate of browning of infested chrysanthemum leaves increased with relative humidity and the number of eelworms. Browning is not a continuous process because the lateral veins act as a barrier to eelworm migration within the leaf. Freeing the leaf surface and eelworms from micro-organisms did not decrease the rate of browning of chrysanthemum leaves, and the eelworm is thought to be the primary cause of leaf discoloration. The saprophytic fungus *Sporobolomyces roseus* is closely associated with browned parts of the leaf, but does not contribute to the discoloration. Chlorogenic acid, isochlorogenic acid and a glycoside of luteolin are the major polyphenolic constituents of chrysanthemum leaves. Chlorogenic acid and isochlorogenic acid are the main substrates for leaf browning, and it is suggested that, when cells are pierced by the eelworm mouth spear during feeding, the polyphenols meet the enzyme polyphenol oxidase and are oxidised and polymerised to form the brown pigments.

Insecticides and Fungicides Department

GENERAL PAPERS

- 9.1. NEEDHAM, P. H. (1960). Investigation into the use of bio-assay for pesticide residues in foodstuffs: Report by P. H. Needham. *Analyst*, Nov. 1960.
- 9.2. WAY, M. J. (1960). Development of insect resistance to insecticides. *N.A.A.S. quart. rev.*

RESEARCH PAPERS

- 9.3. BARDNER, R. (1960). Effect of formulation on toxicity to plants and insects of some systemic insecticidal seed dressings. *J. Sci. Fd Agric.* **11**, 1398-1407.

Wheat, mustard and sugar-beet seeds were treated with dressings containing certain systemic insecticides and various stickers and fillers. Activated carbon, polyvinyl acetate emulsion and a chlorinated diphenyl resin lessened the toxicity of the insecticides to seedlings grown in sand. Polyethylene glycol ethers and polyvinyl alcohol solution also had some effect. Carbon and polyvinyl acetate prolonged the period of systemic action of "Thimet" against the mustard beetle *Phaedon cochleariae* F. and the bird-cherry aphid *Rhopalosiphum padi* L. Mustard plants grown from seed treated with γ -BHC formulated with these materials were slow to attain their maximum insecticidal activity. These effects are attributed to the initial absorption of insecticide by the sticker or filler and its subsequent slow release. Formulations permitting the slow release of insecticides have a practical use because they can combine low phytotoxicity with a long persistence of systemic insecticidal activity.

- 9.4. BROADBENT, L., HEATHCOTE, G. D. & BURT, P. E. (1960). Field trials on the retention of potato stocks in England. *Eur. Potato J.* **3**, 251-262.

(For summary see no. 7.16 on p. 285.)

- 9.5. BURT, P. E., BROADBENT, L. & HEATHCOTE, G. D. (1960). The use of soil insecticides to control potato aphids and virus diseases. *Ann. appl. Biol.* **48**, 580-590.

A replicated trial was done to find whether the insecticides "Thimet" and "Rogor" applied in the soil affected the spread of aphid-transmitted viruses from infected to healthy plants within potato crops. The insecticides were applied at planting as activated carbon formulations at rates equal in cost to three sprays with DDT emulsion at 2 lb. DDT/acre. The infected plants were removed (rogued) in late June.

"Thimet" applied along the furrows with the fertiliser, and "Rogor" applied in individual doses beneath each tuber, kept the plants free from aphids from a week after the plants emerged until early August. "Thimet" in individual doses was less effective, but greatly decreased the aphid infestation. All treatments prevented or greatly decreased the spread of leaf-roll virus, but they only slightly decreased the spread of virus Y. No treatment damaged the plants or depressed yields significantly.

Tubers harvested from the plots treated with insecticides contained only very small quantities of the insecticides, but shoots from them, when infested with adult *Myzus persicae* (Sulz.), carried fewer aphids a week after infestation than did shoots from control tubers. Shoots of tubers from treated plots also grew more slowly than those from the controls.

The aphicidal efficiency of "Thimet" applied as individual doses separated from the tubers by distances of up to 6 inches, decreased as the distance increased, but the effect of distance became less as time passed.

Reasons for the differences in the behaviour of the insecticides are discussed, and the possibilities that the method offers to control virus diseases. The application of insecticides to soil promises to be a useful way of controlling the spread of viruses, provided the harvested crop is free from toxic residues.

- 9.6. DAS, M. (1961). Effect of time and temperature on toxicity of insecticides to insects. II. Tests of DDT on adult *Tenebrio molitor* L. below 10° C. *Ann. appl. Biol.* **49**, 39.

The toxicity of DDT to insects usually increases as the post-treatment temperature is decreased in the commonly used temperature range (30–10°). The toxicity increased further when the post-treatment temperature of adult *Tenebrio molitor* L., dosed by topical application, was decreased from 10° to 6°. However, when the post-treatment temperature was decreased still more (down to –1°), the toxicity by topical application or by injection apparently decreased again. The size of this "positive temperature coefficient" below 6° decreased as time passed after treatment. Differences in toxicity below 6° were more apparent than real, and were the result of differences in the speeds at which symptoms appeared.

The slight toxic action at very low temperatures was evidently not caused by failure of DDT to penetrate the cuticle, or to reach its site of action. More probably, the speed of the chemical or physical process which actually caused paralysis was extremely low at the very low temperatures.

- 9.7. DAS, M. & McINTOSH, A. H. (1961). Effect of time and temperature on toxicity of insecticides to insects. III. Tests of seven poisons in the range 10–28° C. *Ann. appl. Biol.* (**49**, 267–289.)

The contact poisons rotenone, 5:5-dimethyldihydroresorcinol dimethylcarbamate ("Dimetan"), 2-bromomercurithiophen, 2-isovaleryl-1:3-indandione ("Valone"), α -chlordane, toxaphene and DDT were tested, in probit assays, on as many as possible of four insect species (*Oryzaephilus surinamensis* L., *Tribolium castaneum* Herbst, *Tenebrio molitor* L. and *Musca domestica* L.) by applying the poison so that there was no "pick-up" effect, and then keeping the insects at each of two post-treatment temperatures (usually 10 and 28°) for as long as possible.

The same insects were counted repeatedly throughout each test. At each counting, the two ED50's were found, and from these the temperature coefficient of toxic action (ratio of ED50's) was calculated; temperature coefficients were "positive" or "negative", according to whether the toxic action was greater or less at the higher temperature. The time for each ED50 to decrease to a steady value (the end-point) was also found; the inverse of this time was the "speed of action" of the poison. In some tests the end-points were not reached, even though the insects were kept until the proportion dead in the control batches reached about 40%. Temperature coefficients, measured soon after treatment, were most probably temperature coefficients of paralysis only; and those at the end of the test, coefficients of kill, with continuous gradation between.

The results were characteristic of the poison used, and not of the test species.

Rotenone and "Dimetan" each caused an initial paralysis, from which the insects temporarily recovered before dying. In the tests with rotenone, increase in post-treatment temperature increased the speed of the sequence knockdown–recovery–death, and probably the speed of action; the initial temperature coefficient (of paralysis) was negative, but it changed to a positive coefficient as time passed; end-points were not reached. Results with "Dimetan" were somewhat similar, but the coefficients were very small and variable in sign.

In the tests with 2-bromomercurithiophen, "Valone", α -chlordane and toxaphene, the transition from the initial paralysis to death was not interrupted by a period of recovery; all the ED50's decreased steadily in size as time passed, and the observed decrease was greater at the lower temperature. Increase in post-treatment temperature nearly always increased the speed of action, which was greater with "Valone" than with any of the other poisons. The temperature coefficients were initially positive, but became smaller or sometimes negative as time passed, so that an increase in post-treatment

temperature either did not affect the ultimate toxicity (2-bromomercurithiophen and some tests with "Valone") or decreased it (α -chlordane, toxaphene and the other tests with "Valone"); increase in post-treatment temperature also increased the curvature of the line relating ED₅₀ to time after treatment.

In the tests with DDT, which include one series by injection, the ED₅₀'s also decreased steadily as time passed, but the temperature coefficients were consistently negative. Increase in post-treatment temperature did not affect the shape of the ED₅₀-time curve; no general statement can be made about the effect of temperature on speed of action.

Thus, a change in post-treatment temperature can affect the course of poisoning of contact insecticides by affecting their speed of action (which usually increased with post-treatment temperature), or the ultimate toxicity, or the shape of the ED₅₀-time curve, or in some combination of these ways.

Some of the theories about the causes of the negative post-treatment temperature coefficient of DDT are discussed.

- 9.8. DAS, M. & NEEDHAM, P. H. (1961). Effect of time and temperature on toxicity of insecticides to insects. I. Tests of DDT on larvae of *Aedes aegypti* L. *Ann. appl. Biol.* **49**, 32.

The effects of a change in temperature (15–28°) on the toxicity of dilute suspensions of DDT to larvae of *Aedes aegypti* L., as assessed by a photomigration method, depended on the stage of the test during which the temperature was changed. Increase in temperature during exposure to DDT (0.02 p.p.m. for about 1 hour) increased the toxic action. When larvae were left in the suspensions for the duration of the test (3 hours–4 days), increase in temperature throughout the test decreased the toxic action of a very low concentration of DDT (0.002 p.p.m.), but had no effect with higher concentrations (0.1–0.2 p.p.m.). Toxic action was greater in larvae held at a low temperature than in larvae held at a high temperature after treatment (0.025 p.p.m. for 3 hours). Such toxic action was reversible: a change from high to low temperature increased paralysis, and larvae, paralysed at a low temperature, recovered when the temperature was raised.

- 9.9. ELLIOTT, M. (1960). Pyrethrolone and related compounds. *Chem. & Ind.* 1142.

The isolation of pyrethrolone and cinerolone from pyrethrum extract is described; these alcohols with chrysanthemic and pyrethric acids gave pyrethrins I and II and cinerins I and II. The optical rotations of the four esters, earlier in dispute, are discussed. Whereas cinerolone and its derivatives (including cinerins I and II) are stable to heat, pyrethrolone and its derivatives (including pyrethrins I and II) undergo thermal isomerisation, and the side chain double bonds migrate into conjugation with the cyclopentenone ring. These isomerisations increase the negative rotations of the compounds, which probably explains the conflicting optical rotations reported for the pyrethrins. The fifth and sixth pyrethrolone semicarbazones, obtained by earlier workers, are considered to be formed by thermal isomerisation during the isolation procedure, which involved rigorous fractional distillation.

- 9.10. ELLIOTT, M. (1960). The structures of the enols of pyrethrolone. *Proc. chem. Soc.* 406.

Hot methanolic sodium ethoxide converts pyrethrolone into cyclopentanedione (high-boiling enol) and into a cyclopentenedione which has only one side chain double bond (low-boiling enol). The structures of these products were earlier in doubt.

- 9.11. ELLIOTT, M. (1961). Pyrethrins and related compounds II. Infra-red spectra of the pyrethrins and of other constituents of pyrethrum extract. *J. appl. Chem.* **11**, 19.

Infra-red spectra have been widely used in investigations on the pyrethrins and related compounds since 1950, and two analytical methods using infra-red have been described. Crombie stressed the importance of infra-red spectra as criteria of purity and for the elucidation of the structure of compounds in this series, which are often viscous liquids of high boiling point that do not

give derivatives readily. Yet the spectra of the four insecticidal esters themselves (pyrethrins I and II, and cinerins I and II, Fig. 1) have not been published. The spectra of these four compounds are here compared and contrasted with each other and with those of the alcohols, [(+)-pyrethrolone and (+)-cinerolone] and acids [(+)-*trans*-chrysanthemic acid and (+)-*trans*-pyrethric acid] from which the esters are constituted. Further, to help identify the compounds present in flower extracts or other pyrethrum preparations, the spectra of pyrethrosin, of pyrethrol and of the hydrocarbons in the waxes are recorded.

- 9.12. LAST, F. T. (1960). Longevity of conidia of *Botrytis fabae* Sardiña. *Trans. Brit. mycol. Soc.* **43**, 673–680.

The numbers of conidia produced by *Botrytis fabae* on agar media increased up to the 10th day after inoculation, when the average age of conidia was 3 days. Germination in water of conidia from cultures differing in age between 10 and 40 days was equally high, but those from cultures 25 and 35 days old were only $\frac{1}{10}$ and $\frac{1}{100}$ as infective as conidia from 10-day-old cultures.

Suspending conidia from cultures up to 40 days old in a solution (0.2% or higher concentration) of either yeast extract or orange juice partially restored infectivity, as did solutions of sucrose, glucose, mannose and maltose, but fructose and galactose were less effective. Arabinose, xylose, casein hydrolysate, peptone and nucleic acid did not increase infectivity.

Abrading leaves with "Celite" before inoculation increased the numbers of infections produced by spores suspended in water; the increase, as with adding sugars, was greater with old than with young conidia.

- 9.13. LAST, F. T. (1960). Effect of cultural treatments on the incidence of *Striga hermonthica* (Del.) Benth. and yields of sorghum in the Sudan: Field experiments 1957/8. *Ann. appl. Biol.* **48**, 207–229.

Trap-cropping, nitrogenous fertilisers, selective weed-killer sprays (2:4-D) and sorghum varieties affected the incidence of *Striga hermonthica*.

S. hermonthica developed more on the variety Debekri than Feterita. Usually, applying increasing amounts of nitrogen (sulphate of ammonia or urea) progressively decreased the incidence of *S. hermonthica* on Feterita, Dwarf White Milo and Wad Fahl. Early applications were more effective than late applications. Nitrogen given to Debekri never significantly decreased the amount of *S. hermonthica*, and often increased it.

In an experiment on very infertile and heavily infested soil, nitrogen increased the amounts of *S. hermonthica* on all varieties, but less on Feterita than Debekri. The weights of *S. hermonthica* on Feterita reached a maximum with 40 lb. N/acre, but were still increasing after adding 80 lb. N to Debekri.

Weed-killer sprays affected *S. hermonthica* on Feterita and Debekri equally. They delayed the appearance of its aerial stems and usually decreased their subsequent growth. Spraying with 1.6 lb. 2:4-D/acre was usually more effective than with 0.8 lb., and sometimes spraying 3 weeks after sowing was better than after 2 weeks.

Trap cropping with Sudan grass (*Sorghum sudanense*) for 5 weeks, but not for 3, significantly decreased the incidence of *S. hermonthica* in succeeding sorghum crops, and sometimes increased grain yields.

Phosphorus and potassium affected neither the incidence of *S. hermonthica* nor sorghum yields. On lightly infested soil where *S. hermonthica* was not damaging, 80 lb. N/acre trebled grain yields (from 1,140 to 3,530 lb./acre). As infestations increased in severity, the absolute gains decreased, but the relative effects were greater. On crops infested early and severely, yields increased by 820% from 180 to 1,505 lb./acre. Nitrogen applied at sowing and after 3 weeks gave larger increases than later applications.

Yield increases caused by 2:4-D sprays are associated with the delayed emergence of aerial stems of *S. hermonthica*. Where infection developed rapidly and the mean levels of infection were at least 20% within 50 days of sowing, sprays increased both grain and straw yields; where infection developed slowly, only grain yields were increased. Although 1.6 lb. of 2:4-D/acre decreased *S. hermonthica* more than 0.8 lb., they affected yields equally, as did spraying 2 or 3 weeks after sowing.

0.8 lb. of 2 : 4-D/acre and 80 lb. N/acre when applied separately to severely infected crops increased grain yields from 38 lb. in the untreated plots to only 163 and 588 lb./acre respectively, whereas applied together they gave 2,170 lb./acre. In the same experiment nitrogen increased the yields of the less heavily infected Feterita more than those of Debekri. 2 : 4-D affected both varieties similarly.

- 9.14. LAST, F. T. (1960). Incidence of *Striga hermonthica* (Del.) Benth. on two varieties of irrigated sorghum differently manured, spaced and thinned. *Trop. Agric. Trin.* **37**, 309-319.

Foliage of the semi-parasitic *Striga hermonthica* growing on two sorghum varieties, Dwarf Hegari and Feterita 1931, was collected, air dried and weighed on four occasions. It grew at different rates at different stages of sorghum development and reached a peak ca. 5.4 lb./acre/day from 65 to 80 days after planting. Less developed on Dwarf Hegari than on Feterita.

Adding 80 lb. N/acre, as sulphate of ammonia, increased grain and straw yields, but decreased the total aerial growth of *S. hermonthica* from a mean (for the two varieties) of 245 lb. in unmanured crops to 98 lb./acre. The decreases were relatively smaller from 51 to 80 days after planting sorghum, when *S. hermonthica* was developing rapidly, than in earlier and later stages of the host's growth.

Straw yields of unmanured crops of both varieties were similar, ca. 3,350 lb./acre, but Dwarf Hegari yielded more grain. Adding 80 lb. N/acre increased straw yields of the long-strawed Feterita to 9,000 lb. and of the short-strawed Dwarf Hegari to 7,350 lb./acre: it increased mean grain yields of both varieties similarly, from 760 to 3,540 lb./acre.

Widening the spaces between planting holes from 25 to 100 cm. and thinning the number of plants per hole from eight to two did not affect the yields of grain per acre, but quadrupled the yields per plant of both varieties; the straw yields per plant increased by a factor of about $\times 3.2$, instead of $\times 4.0$, with consequent significant decreases per acre. Yields of grain per acre were the same over the whole range of plant populations given by combinations of the various spacing and thinning treatments, viz., 10,000-160,000 plants/acre, but straw yields increased progressively with increasing plant number.

In the first 7 weeks after planting spacing affected weights of *S. hermonthica* per acre but not weights per host—less *S. hermonthica* grew per acre on widely than on closely spaced crops of both varieties. Later, more *S. hermonthica* developed per host spaced at 50 and 100 than at 25 cm., so masking the earlier effects per acre; the increases on Dwarf Hegari were less than on Feterita.

From the start, four times as much *S. hermonthica* grew per host where there were two instead of eight plants/hole, and as a result the weights per acre were unaffected.

- 9.15. McINTOSH, A. H. (1961). Graphical and other short statistical methods for all-or-none bioassay tests. *J. Sci. Fd Agric.* **12** (4).

The full probit method, although time-consuming, is often used to make a statistical analysis of the figures obtained in all-or-none bioassay tests of insecticides or fungicides.

Many rapid approximate methods have been devised as substitutes. One of these is based on ranking; others are arithmetic; and others, based on the use of probits, are graphical.

Logits or angles can be used instead of probits, and often give almost identical results. Each can be calculated on a slide-rule; most of the rapid graphical methods can be applied when they are used; and the method for doing a full analysis is simplest when angles are used.

- 9.16. McINTOSH, A. H. (1961). Some variants and possible errors in the test tube dilution and slide-germination methods for laboratory testing of fungicides. *Ann. appl. Biol.* **49** (3).

A method is given for moulding uniform perspex cavity slides, which are quickly made, almost unbreakable and without joints; they can withstand

strong alkalis, but not strong acids or solvents, and are useful for spore-germination tests of water-soluble fungicides. When the drops of spore suspension-poison mixture in the cavities of these slides or of Böttcher's glass cavity slides are enclosed by cover slips, there is no meniscus effect, and in tests of long duration the same spores can be counted repeatedly.

In such tests errors may arise from sorption of poison on the surfaces of pipettes and tubes (dilution stage) and on slides and cover slips (incubation stage); and from changes in the volume of the drops (incubation stage).

Ions of many metals may be lost by sorption, and the losses are often greater on soft than pyrex glass. Hg was lost rapidly. In a three-stage serial dilution of HgCl₂ solution in soft glassware from 60 to 1.0 p.p.m. of Hg, the loss in strength was 27%. More Hg was lost from HgCl₂ than from phenyl mercuric acetate solutions. The losses on glass or perspex slides with cover slips from solutions containing 1.0 p.p.m. of Hg (but no spores in suspension) were 30–35% in 15 minutes and 61–74% in 24 hours with HgCl₂, but only 5–10% on glass and 35–37% on perspex slides in 24 hours with phenyl mercuric acetate. Increase in temperature (10–25°) slightly increased the loss from HgCl₂ but not from phenyl mercuric acetate solutions. Perspex slides, which were used repeatedly for tests of water-soluble mercury compounds and washed in distilled water after each test, eventually became toxic to conidia of *Botrytis fabae* Sardiña.

When the slides, with drops, are placed in moist chambers for incubation, some evaporation is unavoidable because the air close to them is not initially saturated with water vapour. When the chambers were pre-cooled or pre-warmed, so that the temperature of the air in them was uniform, the loss from 0.30-ml. drops in cavity slides was not serious (about 8%, with or without cover slips, in 48 hours at 10° or 25°). But when the temperature was not uniform, the possibilities of change in drop volume were much greater: in 48 hours, the volume of open drops could decrease by evaporation (44% loss at 10°) or even increase slightly by condensation (3% gain at 25°). When spores have to be counted on several occasions, the evaporation losses may be more serious.

- 9.17. POTTER, C., LORD, K. A. & SOLLY, R. (1960). The mode of action of organophosphorus compounds on insect eggs with special reference to their anti-esterase activity. *Proc. 4th int. Congr. Crep. Prot.* 1957, **2**, 1169–1172.

The hydrolysis of acetyl choline, triacetin and phenyl acetate by homogenates of eggs of *Pieris brassicae* and *Gryllus domesticus* was examined. Enzyme kinetic and inhibition and activation studies indicated that the same enzymes were not present throughout the development of the eggs and that complexes of enzymes were responsible for the hydrolysis of triacetin and phenyl acetate.

The amounts of organophosphorus insecticides to prevent the hatch of *Pieris brassicae* eggs vary with the age of the eggs when the poisons are applied. With increasing age the eggs become more susceptible to TEPP, less susceptible to "Para-oxon" but show little change in resistance to "Dipterex". No relationship between the occurrence of esterases and susceptibility to insecticides was deduced.

- 9.18. SAWICKI, R. M. (1961). A technique for the topical application of poisons to non-anaesthetised house flies for knockdown assessments. *Bull. ent. Res.* **51**, 715.

When a spraying technique is used to assess "knockdown", the amount of insecticide picked up by the flying insects varies and is very difficult to determine. For this reason, topical application, whereby each insect is treated with a given dose of poison, would be preferable, but till now was unsuitable for measuring knockdown, because there was no efficient method to immobilise the insects during dosing. Anaesthetics or cooling affect the response of the insects to the insecticides, using suction to immobilise the insects during dosing means that the insects have to be handled individually, which is laborious and time-consuming.

The method described is rapid; the treatment time of a batch of 10 insects

seldom exceeds 10 seconds, and the total handling time is about 3 minutes. The difference between the dosing time of the first and last insects of a batch is negligible, and the knockdown can be assessed within 15 minutes of dosing.

- 9.19. SAWICKI, R. M. & THAIN, E. M. (1961). The chemical and biological examination of commercial pyrethrum extracts for insecticidal constituents. *J. Sci. Fd Agric.* **12**, 137.

Samples of three commercial pyrethrum extracts were examined chemically and biologically to determine the number of insecticidal constituents they contain. These constituents, which were completely removed from commercial pyrethrum by exhaustive extraction with nitromethane, were separated by displacement chromatography. The insecticidal activity of the eluate was restricted to fractions identified chemically as cinerin I, pyrethrin I, cinerin II and pyrethrin II. Solutions containing the four pure active constituents in the same ratios as in the three commercial extracts had the same activity as the corresponding extracts. If any other insecticidal constituent occurs in commercial pyrethrum extract, its contribution to the total activity is negligible.

- 9.20. WAY, M. J. (1960). Bean aphid control on field beans in relation to the flowering period and to possible honey bee poisoning. *Plant Path.* **10**, 14.

One correctly timed spraying with a suitable systemic insecticide will effectively control *A. fabae* on field bean crops sown before about the beginning of April. The sowing date determines whether the beans are in flower when the insecticide is applied. February-sown crops are likely to be in full bloom when they need spraying, and therefore may be especially dangerous to bees. Autumn-sown crops and crops sown after mid-March will have flowered or not yet flowered, though some bees may be visiting their extra-floral nectaries.

The main recurring danger to bees visiting field beans seems to be from the unnecessarily late spraying with non-selective insecticides of crops sown in March or April.

Entomology Department

DOCTORAL THESES

- 10.1. GERARD, B. M. (1960). The biology of certain British earthworms in relation to environmental conditions. Ph.D. Thesis, University of London.

GENERAL PAPERS

- 10.2. EDWARDS, C. A. & (GUNN, E.) (1960). Autumn tests show better ways to control millipedes. *Comm. Grower*, 591.
- 10.3. MELLANBY, K. (1960). Publication of the results of biological research. *J. Inst. Biol.* **7**, 83-85.

RESEARCH PAPERS

- 10.4. BARNES, H. F. (1960). The resistance of some American wheats to hessian fly of mixed foreign parentage. *J. Kansas ent. Soc.* **33**, 37-44.

Eight American varieties of wheat, resistant to American hessian fly, also had comparable resistance to hessian fly of mixed foreign parentage.

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- 10.5. BARNES, H. F. & ARNOLD, M. K. (1960). The susceptibility of some American wheats to the wheat blossom midges. *J. Kansas ent. Soc.* **33**, 165-174.

Seven American varieties of wheat resistant to hessian fly and one susceptible to it are susceptible to *Contarinia tritici* (Kirby), which is not yet known to occur in North America. All these are also susceptible to the other wheat blossom midge, *Sitodiplosis mosellana* (Gehin), which does occur in North America. Marquillo-Oro \times Triunfo (12858) seems to be less susceptible. The information gained about three other varieties, Marquardts, Durum and Peko, must be discounted, because their ear-burst did not coincide with the midges' flight period.

- 10.6. BARNES, H. F. & ARNOLD, M. K. (1960). Delayed emergence of the pea midge. *Plant Path.* **9**, 52-54.

More *C. pisi* that had completed their larval feeding in the field during 1957 emerged in the Rothamsted Lodge insectary in 1959 than in 1958. A sudden increase in number of emergences occurred in a thundery period in 1959. There are indications that unisexual families occur in the pea midge. The emergence of *S. mosellana*, one of the wheat blossom midges, after spending 18 years as a fully fed larva is noted.

- 10.7. BETT, J. (1960). The breeding seasons of slugs in gardens. *Proc. zool. Soc. Lond.* **135**, 559-568.

Generalised life cycles of five slug species were ascertained from new data, and Barnes & Weil's unpublished data, on weights of individual slugs together with information on the seasonal state of their genital organs.

Arion hortensis hatches mainly in January and February, grows through the summer months to become mature in September and October. These adults live through the winter, laying eggs and gradually losing weight, and die before July of the following year.

The eggs of *Arion subfuscus* are mainly laid in the autumn (late August and September) and hatch sporadically through the winter. The young slugs grow through the spring to become mature in July, and the adults die soon after egg-laying.

Agriolimax reticulatus breeds throughout the year, but the rate depends on the weather and each year there is a period of intense egg-laying associated with the new spring vegetation, giving a summer abundance of individuals.

Milax budapestensis hatches during the autumn and winter, grows through the summer to become mature in late October and November when they mate and eggs are laid in the autumn and throughout the winter. The adults die before July of the following year.

Milax sowerbii probably hatches in early spring, grows throughout the summer, becomes mature, mates and starts to lay eggs in September, October and November. The adults die soon after egg-laying.

- 10.8. COCKBAIN, A. J. (1961). Fuel utilization and duration of tethered flight in *Aphis fabae* Scop. *J. exp. Biol.* **38** (in the press).

Glycogen is used during early flight, but fat is the principal fuel after the first hour and provides about 90% of the energy for a flight of 6 hours. Most of the fat and glycogen reserves are in the fat-body cells of the thorax and abdomen. Calculated metabolic rates during tethered flight ranged from 52-66 cal./g. live wt./hour and 400-500 cal./g. flight muscle/hour. Flight capacity at 25° was directly related to initial fat content and varied between 3 and 8 hours in laboratory-reared aphids and 7 and 12 hours in aphids from a natural infestation.

- 10.9. COCKBAIN, A. J. (1961). Water relationships of *Aphis fabae* Scop. during tethered flight. *J. exp. Biol.* **38** (in the press).

Water loss from tethered aphids during flight was by evaporation and excretion; at least 66% of the loss was by evaporation. The relative amounts

of water loss during prolonged flight were inversely related to relative humidity. The proportion of water in the body and the hydration of lean dry matter remained almost constant during flights of 6 hours. Water loss is not a limiting factor to flight in saturation deficits less than *c.* 23 mm. Hg.

- 10.10. COCKBAIN, A. J. (1961). Viability and fecundity of alate alienicolae of *Aphis fabae* Scop. after flights to exhaustion. *J. exp. Biol.* **38** (in the press).

Longevity, reproductive rate and capacity, and nymph viability of aphids flown to apparent exhaustion (for 3–9 hours), and subsequently allowed to feed on host plants, were similar to those of aphids flown for only $\frac{1}{4}$ hour. Unlike fresh aphids, exhausted ones were unable, or reluctant, to fly on the following day, possibly because of the early onset of flight muscle autolysis. Results indicate that long migratory flights are unlikely in themselves to affect the reproductive potential of aphids, and that alienicolae of *A. fabae*, having settled on a suitable host after exhaustion, are unlikely to fly again.

- 10.11. DOBSON, R. M. & MORRIS, M. G. (1961). Observations on emergence and life-span of wheat bulb fly (*Leptohylemyia coarctata* (Fall.)) under field-cage conditions. *Bull. ent. Res.* **51**, 803–821.

Emergence and life-span of wheat bulb fly (*Leptohylemyia coarctata* (Fall.)) were studied by the use of the "Field-Cage-Marking" technique. Emergence was investigated by observing the numbers of flies emerging daily from an area of infested wheat enclosed by a cage of fine mosquito netting, and life-span by making a daily census of marked and individually recognisable flies which had been liberated in the cage. Flies were handled only when being marked, and in the latter part of the work all observations were made without touching either them or the wheat.

Flies were chilled to render them comatose for marking and under certain circumstances this and the marking was harmful. Attempts were made to decrease these harmful effects.

Emergence dates varied from year to year, depending on the temperatures of spring and early summer, and there were also considerable differences between the emergence dates of populations of adjacent fields in the same year. Consistently, males appeared before females.

The ratio of flies seen to the number known to be alive on each day varied according to weather, and flies were more difficult to find on windy days than on calm ones and on bright days than on dull ones.

The observed life-spans of both sexes varied greatly—up to a maximum of 75 days for females and 55 days for males. An exact statement of mean life-span was, however, valueless because there was a tendency for flies emerging later in the season to be less long-lived than those emerging earlier. Most flies of both sexes lived for over 30 days. The observed life-spans fall short of the true life-spans by amounts which depend on the proportions of living flies seen each day. Two methods are shown by which the mean unrecorded life-span can be calculated.

- 10.12. EDWARDS, C. A. (1960). The ecology of Symphyla. Part II. Seasonal soil migrations. *Ent. exp. & appl.* **2**, 257–267.

Seasonal changes in the vertical distribution of *Scutigervella immaculata* Newport and *Symphylella vulgaris* Hansen in cultivated soils were studied. In bare soil outdoors there were high surface numbers in spring, low in summer with a second increase in autumn. The distribution pattern was similar in bare greenhouse soil, except that spring migrations to the surface soil occurred earlier, the summer exodus from the surface was more marked and the autumn increase much reduced. Growing plants attracted *Scutigervella immaculata* to the surface even under adverse soil conditions, but had little influence on *Symphylella vulgaris*. The results are discussed in relation to other work.

- 10.13. EDWARDS, C. A. & (DENNIS, E. B.) (1960). Observations on the biology and control of the Garden Swift Moth. *Plant Path.* **9**, 95-99.

The Garden Swift moth, *Hepialus lupulinus* L., is a common soil pest of horticultural crops. The host range of this pest is reviewed and added to. Winter attacks of lettuce and anemones by the larvae were studied and replicated trials made to test the efficiency of DDT, BHC, dieldrin and aldrin soil drenches. Of the materials tested a solution of DDT emulsion containing 0.05 a.i. was both the most effective, cheapest and most persistent. Evidence was accumulated that the moth completes its life cycle in one year.

- 10.14. EDWARDS, C. A. & (DENNIS, E. B.) (1960). Some effects of aldrin and DDT on the soil fauna of arable land. *Nature, Lond.* **188**, 767.

The effects of rates of insecticides commonly used on the soil fauna of fallow arable land were studied in a replicated trial. Sixteen 2-inch diameter soil cores were taken from each treatment at 2-3 monthly intervals and the fauna extracted by a modified Salt and Hollick technique. Aldrin decreased and DDT increased the Collembola population. Both insecticides very significantly decreased the populations of mites, dipterous and coleopterous larvae, thrips, pauropods and symphylids. Numbers of root aphids were greatly decreased by aldrin, but not by DDT; neither insecticide affected the populations of earthworms and enchytraeid worms significantly.

- 10.15. FRENCH, R. A. & (WHITE, J. H.) (1960). The Diamond-back Moth outbreak of 1958. *Plant Path.* **9**, 77-84.

At the end of June and the beginning of July 1958 a large immigration of the Diamond-back Moth (*Plutella maculipennis* (Curt.)) occurred on the east coasts of England and Scotland. The entomological information indicated that these insects had come from an easterly direction, possibly from North-West Russia. Trajectories of the winds blowing at this time lead back to a similar region and, by their use, an attempt is made to delineate approximately the area of origin.

- 10.16. HEATH, G. W. (1960). Ley deterioration and soil insects. *J. Brit. Grassl. Soc.* **15**, 209-211.

Two insecticides were applied to a 5-year-old ley and their effects on yield and soil fauna were studied a year later. Aldrin (2 lb. actual toxicant/acre) or dieldrin (1 lb. actual toxicant/acre) was incorporated in a standard dressing of compound fertiliser.

One year after treatment the yield of dry matter was significantly higher on dieldrin plots than on plots receiving fertiliser alone. The soil fauna was examined in dieldrin and control plots. The wireworm (*Agriotes* spp.) populations were 80,000 and 400,000 per acre respectively. The increase in herbage yield was ascribed to the decrease in number of wireworms. Mite and Collembola populations were very significantly decreased by dieldrin: the effect of this on the breakdown of soil organic matter is discussed. Predaceous insects were effected by insecticides, but their resurgence rate can be expected to keep pace with that of wireworms.

- 10.17. JOHNSON, C. G. (1960). A basis for a general system of insect migration and dispersal by flight. *Nature, Lond.* **186**, 348-350.

Whenever the beginning of a mass migration has been recorded it has shown that the migrants are relatively newly emerged insects on a very early, often the first, flight. The consequences of this to the general approach to migration and dispersal studies is discussed.

- 10.18. JOHNSON, C. G. (1960). The relation of weight of food ingested to increase in body-weight during growth in the bed-bug, *Cimex lectularius* L. (Hemiptera). *Ent. exp. & appl.* **3**, 238-240.

The increase in body weight of successive instars (weighed before feeding) is of the order of 30% of the weight of the food (blood) ingested at each instar

except with the 1st-2nd instar, where it is approximately 40%. The gross efficiency with which food is used to increase body weight does not vary appreciably with temperature between 20° and 30°.

- 10.19. LONG, D. B. (1960). Larval movement and infestation in the wheat bulb fly, *Leptohylemyia coarctata* Fall. *Bull. ent. Res.* **51**, 405-414.

The ability of newly hatched larvae of the wheat bulb fly to move through 9 inches of soil and infest wheat plants depends on the nature of the soil and its pH. In the soils tested larvae were most successful in sandy loam, 28% infesting plants, less so in clay loam, 19% and least in peaty loam, 2%. Larvae-infested plants grown in clay loam within a pH range of 4.9-7.8 with a possible optimum at pH 6.2. The relative failure to infest in peaty loam is apparently because this soil impedes larval movement rather than it interferes with the finding of host-plants.

In plot experiments no predominating direction of larval movement was observed. Newly hatched larvae can travel up to at least 21 inches before they enter a shoot and feed. Three-quarters of the larval life may be spent in this shoot, while the weight increases about 60 times. Movement is usually from this shoot to another along rows. In subsequent feeding, larval weight increases by a further factor of 15. The larvae damaged an average of two shoots each and travelled up to a maximum distance of 33 inches, measured in a straight line from point of release, throughout their entire life-span.

- 10.20. MELLANBY, K. (1961). Slugs at low temperatures. *Nature, Lond.* **189**, 944.

Slugs can move and feed at low temperatures, so are well fitted to be agricultural pests in winter. *Agriolimax reticulatus* is active below 0.8°, *Arion hortensis* is seldom active below 5°. No acclimatisation to high or low temperatures was found in slugs, which thus differ from many insects, amphibia and fish.

- 10.21. MILLER, B. S. & (SWAIN, T.) (1960). Chromatographic analyses of the free amino-acids, organic acids and sugars in wheat plant extracts. *J. Sci. Fd Agric.* **6**, 344-348.

Plants of three hard red winter wheat varieties differing in their resistance to attack by hessian fly (*Mayetiola destructor* Say) were compared at the fourth leaf stage for their content of constituents extractable by 80% ethanol. Eleven amino-acids, five organic acids and two inorganic acids were identified. Seven sugars were separated, two of which were unidentified polysaccharides. The main difference was that the susceptible variety (Tenmarq) contained allulose, or allulose in combination with some other component. The semi-resistant variety (Ponca) contained less allulose and the resistant variety (C.I. 12855) contained none. Sorbitol was found in Tenmarq, but not in the other varieties.

- 10.22. MILNE, D. L. (1960). The gall midges (Diptera: Cecidomyiidae) of clover flowerheads. *Trans. R. ent. Soc. Lond.* **112**, 73-108.

A study of the gall midge (Diptera: Cecidomyiidae) fauna of clover heads has shown that there are three species, namely *Dasyneura leguminicola* Lintner, *D. gentneri* Pritchard and *Tricholaba barnesi* sp. n., whose larvae destroy clover seed in Britain. *Dasyneura gentneri* and *D. leguminicola* are separated morphologically and biologically. The morphological criteria used are demonstrated to be valid in separating other closely allied *Dasyneura* species, namely *D. mali* Kieffer from *D. pyri* Bouche and *D. affinis* Kieffer from *D. violae* Loew.

Seven other gall midge species occur on clover heads in Britain. The larvae of two of these, *Phaenobremia aphidivora* Rübssaamen and *Lestodiplosis trifolii* Barnes, are predatory on aphids and other gall midge larvae, respectively. The feeding habits of the remaining five species, namely *Clinodiplosis leguminicola* sp. n., *Giardomyia britannica* sp. n., *Isodiplosis deuttera* sp. n., *Brachyneura squamigera* Winnertz and *Contarinia* sp., are not known, although

it is suggested that larvae of *Isodiplosis deutera* may feed on decomposition products or on fungus spores.

Illustrated keys are given for the identification of males, females and larvae of gall midges occurring on clover heads in Britain.

- 10.23. RAW, F. (1960). Observations on the effect of hexoestrol on earthworms and other soil invertebrates. *J. agric. Sci.* **55**, 189–190.

When hexoestrol or stilboestrol is used to aid meat production most of the oestrogen is excreted by the treated animals, and so reaches the soil, where it may affect the soil fauna.

Laboratory experiments showed that activity of *L. terrestris*, *A. caliginosa* and *A. chlorotica* was unaffected by 15 mg. hexoestrol in 500 g. of soil. Activity and reproduction of *A. caliginosa* was unaffected by 10 mg. hexoestrol in 500 g. soil, but 100 mg. and over affected activity and stopped reproduction. This is far in excess of amounts ever likely to be reached in land grazed by treated cattle. Egg capsules of *A. caliginosa* and *A. chlorotica* developed normally in a saturated aqueous solution of hexoestrol.

When grass plots grazed by treated and untreated bullocks were sampled no effect on the soil fauna due to grazing by implanted bullocks was observed.

- 10.24. RAW, F. (1960). Earthworm population studies: a comparison of sampling methods. *Nature, Lond.* **187**, 257.

The accuracy of estimates of earthworm populations got by hand sorting soil samples was tested by using a washing method to see how many more worms could be recovered from soil samples already hand sorted.

Hand sorting recovered only 52% of the number and 84% of the weight of worms from samples from wet hill grassland with a surface mat and poor soil structure; proportionately more of the large than of the small worms were recovered. Hand sorting was no quicker than washing.

With soil samples from grassland with no surface mat on a light and a heavy well-drained soil, hand sorting recovered 89% of the total number and 95% of the total weight of worms found, and was much quicker than washing, but with samples from an old arable field on heavy soil with poor structure, hand sorting recovered only 59% of the total number and 90% of the total weight of worms found, and was no quicker than washing.

The washing method checks the efficiency of hand sorting, and, for some habitats, more accurately estimates the population.

- 10.25. RICHES, J. (1960). Damage to the oat panicle by the Frit Fly. *Ent. exp. & appl.* **3**, 173–184.

About 2,000 panicles (60,000 spikelets) of known bursting date from small plots of oats were dissected. Spraying young oat plants with DDT against first-generation attack also decreased panicle attack. The spraying causes physical differences between the sprayed and the unsprayed areas—namely, spraying gives a higher plant density and uniformity of panicle bursting date. Main grain is more liable to attack than bosom grain.

Blindness of oats is discussed, and results given to support the theory that one type of blindness is caused by frit fly attacking the immature grain.

- 10.26. SOUTHWOOD, T. R. E. (1960). The flight activity of Heteroptera. *Trans. R. ent. Soc. Lond.* **112**, 173–220.

Details are given of the Heteroptera taken in various light and suction traps at Rothamsted, some of which ran for several years, from shorter periods of trapping at Kawanda (Uganda) and Tafo (Ghana), and with suction traps at different heights at Cardington, Beds. The new information provided by the present study on the level of flight activity of various taxa is reviewed. Closely related taxa often differ greatly, e.g., the activity of the Cydnidae as a family is high, of the Pentatomidae, low; that of the genus *Lygus*, high, of *Liocoris*, low; that of *Orthops kalmi* L. high, and of *O. campestris* L. low.

- 10.27. TAYLOR, L. R. (1961). Aggregation, variance and the mean. *Nature, Lond.* **189**, 732-735.

Sets of samples from populations at various levels of density were examined to find the relation between the mean and variance. The 24 examples used, aggregated to widely different degrees, are all satisfactorily described by a power law: variance is proportional to a fractional power of the mean ($s^2 = am^b$), in which the power is an Index of Aggregation ranging from 0.70 to 3.08 in the examples cited. The law also gives a general transformation for all degrees of aggregation:

$$f(x) = Q \int m^{-bl^2} dm$$

Bee Department

GENERAL PAPERS

- 11.1. BUTLER, C. G. (1961). The efficiency of a honeybee community. *Endeavour*, **20**, 5-10.
- 11.2. FREE, J. B. (1960). Amendments made by F. W. L. Sladen to his book "The Humble-Bee". *Bee World*, **41**, 8-9.
- 11.3. FREE, J. B. (1960). The pollination of fruit trees. *Bee World*, **41**, 141-151, 169-186.
- 11.4. SPENCER-BOOTH, YVETTE (1960). Feeding pollen, pollen substitutes and pollen supplements to honeybees. *Bee World*, **41**, 253-263.

RESEARCH PAPERS

- 11.5. BAILEY, L. (1960). The epizootiology of European Foulbrood of the larval Honey Bee, *Apis mellifera* Linnaeus. *J. Insect Path.* **2**, 67-83.

Larvae, artificially infected when 0-1 day old with *Streptococcus pluton* (White) and placed in colonies, were usually ejected by adult bees. Ejection was delayed from colonies deprived either of unsealed brood or their queen, or which were reinforced with adult bees. The faeces of surviving larvae whose weight was subnormal contained many viable cells of *S. pluton*. Colonies reinforced with unsealed brood removed more infected larvae than usual. It is concluded that infected larvae are ejected when larval food is merely adequate, as it may be when a colony is growing rapidly; and they are kept when larval food is more abundant, as it may be when brood-rearing is retarded.

Natural outbreaks of disease occurred when brood-rearing, in colonies heavily infected with *S. pluton*, was increasing during nectar flows, which was also when secondary infection with *Bacterium eurydice* (White) increased. At such times larvae heavily infected with both organisms may die more quickly than they are being removed. At the same time infection of new larvae with *S. pluton* seemed to decrease: transmission of *S. pluton* was presumably checked by the death and ejection of unsealed larvae. Thus outbreaks usually seemed to be self-limiting. Colonies eject introduced larvae even more readily after the main nectar flows are over, which may account for the difficulty in causing disease artificially at this time.

- 11.6. BUTLER, C. G. (1960). The significance of queen substance in swarming and supersedure in honey-bee (*Apis mellifera* L.) colonies. *Proc. R. ent. Soc. Lond.* (A) **35**, 129-132.

Measurements showed that both superseded and old mated swarm queens from uncrowded colonies contained only about one-quarter as much queen substance as mated laying queens from colonies without queen cells. Old

mated swarm queens from overcrowded colonies had about as much as the mated laying queens.

The demand for queen substance by workers from colonies preparing to swarm was found to be no greater than that by workers from non-swarving colonies.

It appears, therefore, that queen rearing by uncrowded colonies preparing to supersede their queen or to swarm with her results from the queen producing too little queen substance, but that queen rearing in an overcrowded colony before swarming is not necessarily due to inadequate production of queen substance, but could be due to its inefficient collection and distribution.

11.7. BUTLER, C. G. (1960). Queen recognition by worker honeybees (*Apis mellifera* L.). *Experientia*, **16**, 424-427.

Living queens attract worker honeybees from a short distance on account of an odour they produce, which persists for several months after death. The substance responsible is removed when queens are extracted with ethanol, and the material so extracted is attractive to worker bees. There is reason to believe that its attractive odour is only gradually released from a queen's body.

Queen substance can also be extracted from queens' bodies in ethanol, but pure queen substance (9-oxodec-2-enoic acid) does not have an odour that attracts workers even when offered in large amounts. It is clear, therefore, that queen substance is not responsible for the odour which probably attracts workers to a queen and so helps them to find queen substance, but does not itself inhibit queen rearing.

11.8. BUTLER, C. G. (1960). Queen substance production by virgin queen honey-bees (*A. mellifera*). *Proc. R. ent. Soc. Lond.* (A) **35**, 170-171.

Little or no queen substance was produced by virgin queens 24 hours old, but virgins 1 week old had significantly more and those 3 weeks old, whether laying or not, had much more but less than well-established mated laying queens. In fact, virgins 1 week old each had about one-quarter as much queen substance as a mated laying queen (i.e., about as much as a superseded queen or a swarm queen from an uncrowded colony) and those 3 weeks old had about one-third as much.

It was concluded that the inability of a virgin queen to inhibit queen rearing, and also perhaps the difficulty of replacing a virgin queen of a colony by a mated laying queen, are probably both due to the low level of queen substance produced by virgin queens. It is clear, however, that colonies do not distinguish between virgin and mated queens by the relative amounts of queen substance on their bodies.

11.9. FREE, J. B. & SPENCER-BOOTH, YVETTE (1959). The longevity of worker honeybees (*Apis mellifera*). *Proc. R. ent. Soc. Lond.* (A) **34**, 141-150.

Groups of 100 newly emerged worker honeybees were introduced weekly into each of four colonies from March to October and their longevity ascertained. The mean length of life of bees introduced in spring and summer was lower than had previously been supposed. It decreased in accordance with their date of emergence from just over 5 weeks in March to about 4 weeks in June, the weekly death-rate at all ages being greater in June than at any other time.

The weekly death-rate of bees emerging in August was considerably lower than for bees emerging during the previous 3 months. Many bees emerging in August and September overwintered, some surviving until May; there was no correlation between their age and date of death the following year. Some bees emerging in October survived until June. The longest lived bees survived between 217 and 228 days. There were marked differences in longevity of bees from different colonies.

- 11.10. FREE, J. B., FREE, N. W. & JAY, S. C. (1960). The effect on foraging behaviour of moving honeybee colonies to crops before or after flowering has begun. *J. econ. Ent.* **53**, 564-566.

Experiments on peach, sweet cherry, apple, bird's-foot trefoil, lucerne and red clover have shown that delaying moving colonies to a crop until flowering has begun increases the proportion of foragers which visit it.

- 11.11. SIMPSON, J. (1960). The age of queen honeybees and the tendency of their colonies to swarm. *J. agric. Sci.* **54**, 195.

Analysis of a commercial beekeeper's records showed that colonies with 2-year-old queens are much more likely to have occupied queen cells than those with 1-year-old queens.

Statistics Department

GENERAL PAPERS

- 12.1. GOWER, J. C. (1961). The analysis of experiments on the Rothamsted computer. *Manchester stat. Soc. Group Meetings, Session 1959-60*, 40-49.
- 12.2. LEECH, F. B. (1961). Food losses through animal disease. *Proc. Nutr. Soc.* **20**, 20-24.
- 12.3. (PEREIRA, H. C.) & VERNON, A. J. (1960). Practical aspects of field experimentation in Africa. *E. Afr. Agric. For. J.* **26**, 35-41.
- 12.4. YATES, F. (1961). The use of electronic computers in the analysis of replicated experiments, and groups of experiments of the same design. *Bull. Inst. agron. Gembloux*. (In the press.) (French text: *Biométrie-Praximétrie*, **3-4**, 3-15, (1960).)

RESEARCH PAPERS

- 12.5. (BARTLETT, M. S.), GOWER, J. C. & (LESLIE, P. H.) (1960). A comparison of theoretical and empirical results for some stochastic population models. *Biometrika*, **47**, 1-11.

This paper is in two sections. The first part establishes a number of theoretical results for stochastic population models in both discrete and continuous time. Models involving one or two species are considered, and formulae for the mean, variance, skewness and where appropriate covariance of the population distributions for stationary distributions are obtained, to both the first and second order of approximation.

Explicit formulae are obtained for the logistic model of population growth, and the second part of the paper compares these formulae with results obtained from numerical sampling experiments on the discrete time model. The agreement between the observed moments and the theoretical approximations for the discrete time model are very satisfactory. As was to be expected, the agreement with the continuous time approximation is not quite so good, but by reducing the discrete time interval the moments for the two models approximate more closely to each other.

Some results are also given comparing numerical results for a system of two competing species. The agreement with theory is again satisfactory.

- 12.6. BOYD, D. A. (1961). Fertiliser responses of maincrop potatoes: a re-examination of the experimental evidence. *J. Sci. Fd Agric.* (In the press.)

The results of recent manurial experiments on maincrop potatoes were re-examined to determine: (i) what general changes in level of response had occurred since Crowther and Yates' summary in 1940, and (ii) the nature of

the interactions between nutrients and their influence on the form of the fertiliser response curve and on optimal fertiliser dressings.

Average responses to 0.8 cwt. N, 1.0 cwt. P_2O_5 and 1.5 cwt. K_2O /acre in over 100 experiments done since 1940 were 1.8, 1.4 and 2.0 tons/acre respectively, and these do not differ by more than 0.2 tons/acre from Crowther and Yates' figures.

Most of the recent experiments on mineral soils showed large interactions between nutrients which affect both the magnitude of the response to a given dressing and the degree to which the response fell off with increasing levels of dressing. The concept of a "standard" response curve of the exponential form did not adequately describe the response surface revealed in these experiments. Evidence is presented that, for any nutrient, the response curve rises to a maximum and then begins to fall, and that the level of dressing at which the fall begins depends on the amounts of the nutrient present in the soil, on the supply of the other plant nutrients, both by the soil and from fertilisers and farmyard manure, and on other factors, such as the method of fertiliser application.

For fertiliser applied over the ridges at planting, optimal dressings were estimated to be 1.0–1.2 cwt. N and P_2O_5 /acre and 1.5–2.0 cwt. K_2O /acre, but the optima were ill determined because the fertiliser rates tested in most of the experiments were too low.

- 12.7. BOYD, D. A. (1961). Series of experiments. *N.A.A.S. Quart. Rev.* Spring 1961.

The article discusses the planning of local and national series of experiments, dealing in particular with the number of sites and their selection, and the effects of season, and emphasises the importance of field and uniform recording to enable the effects of external factors on the experimental treatments to be assessed. In series of factorial experiments more detailed knowledge of the effects of individual treatment combinations is being sought, and having regard to recent improvements in experimental technique, this suggests that modifications may also be required in some aspects of experimental design and analysis.

- 12.8. BOYD, D. A. (1961). Current fertiliser practice in relation to manurial experiments. *Proc. Fertil. Soc.* (In the press.)

The paper discusses the use of fertilisers on potatoes, sugar beet and cereals in relation to the fertiliser requirements of these crops indicated by recent experimental results. For the country as a whole, the average rates of application of N, P and K fertilisers for potatoes, N and K fertiliser for sugar beet and N for cereals are probably not far from the average optima; phosphorus requirements of sugar beet are usually small. There is little modern information on the P and K requirements of cereals.

Fertiliser requirements of potatoes and sugar beet differ substantially from district to district, but differences in fertiliser use are small. Within a district, however, there are large differences in fertiliser use from farm to farm, which appear to be largely unrelated to factors known to influence crop requirements, such as soil nutrient status, previous cropping and use of farmyard manure. Potatoes and sugar beet are manured very similarly, but their requirements of P are quite different.

Nitrogen requirements of cereals vary over a very wide range, both from season to season and in relation to such factors as level of soil fertility, previous cropping and manuring and disease incidence. Except that farmers' decisions on whether or not to apply N were to some extent related to previous cropping, it is doubtful if the large variation in practice from farm to farm was related to real differences in response.

- 12.9. BOYD, D. A., CHURCH, B. M. & HILLS, M. G. (1961). Fertiliser practice in England and Wales. Part I. General features of fertiliser consumption, 1956–57. *Emp. J. exp. Agric.* **29**, 35–44.

Results from 35 surveys of fertiliser practice in England and Wales done in 1957 are used to provide estimates of average consumption of N, P and K

within three groups of districts: (1) arable districts, (2) lowland grassland districts, and (3) English uplands and Wales.

Arable farming districts used between two and three times as much N and K per acre crops and grass as the lowland grassland districts, and four to five times as much as the upland districts. Much the same differences were found for water-soluble P, but more basic slag and rock phosphate were used in grassland districts.

Changes in consumption are examined, using the results of previous surveys. Between 1953 and 1957 there were large increases in use of N and K on tillage and leys, mainly, but not entirely, from increases in the proportions of crop acreages treated; the absolute increases were smaller for permanent grass, but as percentages of 1953 consumption were very large, except in upland districts where little change occurred. In general, the proportions of crop acreages receiving P changed little, but where compound fertilisers were replacing the use of straight P, rates of application were much lower.

The total amount of farmyard manure produced in England and Wales in 1956-57 is estimated to have been about 50 million tons, or just under 2 tons/acre of crops and grass. Except for a small increase in lowland grassland counties, there has been little change since a previous estimate in 1944.

- 12.10. BUCK, S. F. (1960). A method of estimation of missing values in multivariate data suitable for use with an electronic computer. *J. R. statist. Soc. B.*, **22**, 302-306.

Estimation of statistical parameters from multivariate data results in wasted information if units with incomplete data are rejected entirely, and perhaps in inconsistencies in the variance-covariance matrix if the variances and correlation coefficients are estimated from all available data on individual variates and pairs of variates respectively. An alternative is to estimate the missing values by regression techniques and to calculate a revised variance-covariance matrix. This method is suitable for use with an electronic computer. It is shown that with this method the resultant covariances are unbiased, but that the variances require correction for bias. A numerical example is given.

- 12.11. CHURCH, B. M. (1960). An investigation of sampling dried pyrethrum flowers from bulk. *Trop. Sci.* **2**, 200-218.

The general requirements for a reference sampling method, and requirements for acceptable methods of obtaining routine commercial samples from bulk, are briefly discussed.

A reference method is described that gives unbiased samples of dried pyrethrum flowers to provide a standard against which to test routine sampling, and is also suitable for direct use in experimental work. The method is based on the use of "riffles" which decrease the entire bulk of flowers by repeated subdivision. A method is given for calculating the numbers of samples, and of laboratory determinations per sample, needed to give estimates of required accuracy.

The percentage pyrethrin content of 2-4 lb. reference samples has a standard deviation which is $1\frac{1}{2}$ -2% of the mean content. Laboratory errors must also be taken into account when deciding on the accuracy required in sampling. The standard deviation for spectrophotometric determinations on sub-samples from the same sample was also about $1\frac{1}{2}$ % of the mean under favourable conditions, but could be substantially greater.

Tests of a sampling machine in routine use showed that it tended to over-estimate the percentage pyrethrin content of bulks of flowers by about 0.02 or $1\frac{1}{2}$ -2% of the mean. The bias was fairly consistent and not large compared with the random errors of routine determinations. The bias could be accounted for by the fact that the machine, which sampled from a stream of flowers falling from the end of a conveyor belt, collected proportionately more of that part of the stream falling farthest from the belt. Random errors attributable to machine sampling are shown to be small compared with those from sample reduction and analysis.

Some information obtained incidentally on the deterioration of ground pyrethrum flowers is summarised.

- 12.12. CHURCH, B. M., BOYD, D. A. & HILLS, M. G. (1961). Fertiliser practice in England and Wales. Part II. Manuring of cereals. *Emp. J. exp. Agric.* (In the press.)

Detailed information is presented on cereal manuring in England and Wales in 1956-59, and regional trends in practice since 1953 are examined. Over the country as a whole, average N and K consumption per acre of cereals increased by almost half since 1953, while phosphate consumption had changed little.

Within broad farming type regions, the average manuring of cereals in different districts is generally similar. In East Anglia (excluding the fens) and southern England, where all but a small proportion of the cereals received complete fertiliser, average nitrogen dressings to winter wheat were close to the probable optima. Elsewhere a substantial part of the acreage received no fertiliser, and average nitrogen dressings were lower. The scope for increases in use of fertilisers on cereals in these areas is doubtful, because of residual nutrients from previous crops, ploughing in of dung and climatic factors.

Although factors such as previous cropping and methods of fertiliser application are shown to be associated with differences in average manuring, it seems unlikely that the large differences within regions in the manuring of individual farms correspond in general to differences in crop requirements.

- 12.13. DOBSON, R. M. & MORRIS, M. G. (1961). Observations on emergence and life-span of the wheat bulb fly (*Leptohylemia coarctata* (Fall)) under field-cage conditions. *Bull. ent. Res.* **51**, 803-821.

See no. 10.11 above for summary.

- 12.14. (EGDELL, J. W. *et al.*) & WESTMACOTT, M. H. (1960). Some studies of the colony count technique for soil bacteria. *J. Soc. appl. Bact.* **23**, 69-86.

A series of co-operative experiments compared the bacterial colony counts from soil obtained by workers in different laboratories using soil extract agar and other media for the determinations. The earlier experiments had not given a reasonable degree of reproducibility of results between laboratories even when the plating technique was carefully prescribed.

By modification and more rigid standardisation of the technique, closer agreement of results was obtained. It is suggested that, when co-operative investigations are contemplated, the participating laboratories should check their results by the examination of "control" soils.

No evidence could be obtained to support the suggestion that higher colony counts are obtained by the use of soil extract media containing extract prepared from the same soil as the sample tested. The source appears to be immaterial so long as the soil for extract preparation is not of extreme type and has been well manured and cultivated.

The plate counts obtained from 10^{-5} and 10^{-6} dilutions of the same soils were compared in some experiments. The colony counts for the 10^{-6} dilution, expressed as colonies/g. dry soil, were between $1\frac{1}{2}$ and 2 times those for the 10^{-5} dilution. It is thus clear that counts of soil samples cannot be compared if they have been drawn from different dilutions.

- 12.15. GIBBS, A. J. & GOWER, J. C. (1960). The use of a multiple transfer method in plant virus transmission studies: some statistical points arising in the analysis of results. *Ann. appl. Biol.* **48**, 75-83.

See no. 7.22 above for summary.

- 12.16. GOWER, J. C. (1961). A note on some asymptotic properties of the logarithmic series distribution. *Biometrika*. (In the press.)

Formulae are given to calculate $S(x, R) = \sum_{r=R+1}^{\infty} \frac{x^r}{r}$, the remainder term in

the logarithmic series, which are valid for high values of R , and values of x close to unity. These are of value when dealing with extreme values of the parameters appearing in the logarithmic series distribution such as have arisen in C. B. Williams' recent study of the possible distribution of the number per species for all the insects in the world. Bounds are given for the errors involved when making the recommended approximations.

- 12.17. HEALY, M. J. R., (McLAREN, A. & MICHIE, D.) (1960). Superpregnancy in the mouse. III. Foetal growth. *Proc. Roy. Soc. B*, **153**, 367-379.

Polytocous mammals show an inverse relation between the number of young in the litter and the size of the young at birth. It has been customary to attribute this to prenatal competition for a limited pool of nutrients in the maternal circulation (Hammond & Marshall, 1952).

The present study was undertaken to subject the traditional theory to quantitative test. Pregnant mice were killed shortly before term and their foetuses were weighed. Some of the pregnancies had resulted from natural ovulation. Others were obtained by inducing superovulation with hormone treatment, some in adults and others in sexually immature females.

Analysis of the foetal weights yielded several results at variance with the predictions of the theory of competition, notably:

1. Foetal growth was more affected by the presence of other foetuses if these were in the same, rather than in the opposite, uterine horn.
2. Foetuses dying in mid-pregnancy, when their nutritional demands would still be small, exerted effects upon the growth of the survivors comparable to those exerted by foetuses surviving the middle period.
3. The signs of nutritional stress exhibited by sexually immature females carrying abnormally large numbers of foetuses were not accompanied by a reduction in foetal weight after due allowance for foetal number.
4. The foetuses occupying the top (ovarian) position in the uterine horn were on average significantly lighter than the others in the same horn.

These results can be better accommodated by an alternative theory of foetal growth (Eckstein, McKeown & Record, 1955) which proposes that the chief regulating factor is the pressure at which maternal blood is supplied to the placenta. Some other observations on foetal growth in mice are cited which are also consistent with the haemodynamic theory.

- 12.18. LEECH, F. B., DAVIS, M. E., (MACRAE, W. D. & WITHERS, F. W.) (1960). *Disease, wastage and husbandry in British dairy herds: report of a national survey in 1957-58*. London, Ministry of Agriculture, Fisheries and Food.

Records of disease, culling and mortality were obtained from a random sample of the dairy herds of Great Britain, for the 12-month period 1 October 1957 to 30 October 1958. The data were used to calculate national estimates, that is, estimates of the true values of the statistics for the whole population of 132,000 dairy herds. In addition, regional estimates were calculated for eight subdivisions of the country. One of the major items in the report is the description of and comment on the differences between these regional estimates.

The analysis of 14 sets of data concerning size of herd and farm, breed of cow, aspects of management, husbandry and output revealed substantial and, frequently, large regional differences for every set of data.

The data on morbidity are regarded as records of symptoms that were recognised by the farmer or his staff as symptoms that affected, or threatened to affect, the economic value of the animal. The outstanding feature of the diseases of dairy herds was the importance of diseases peculiar to the female, particularly mastitis and those closely associated with parturition. Of the remainder, the most important specific diseases appear to have been Johne's disease, grass tetany and foul-in-the-foot. The incidence of several important diseases differed considerably between breeds, and in herds of different sizes and in different parts of the country.

A characteristic feature of most of the diseases analysed was that they affected a few herds seriously, whereas most herds reported little or none. This situation is characteristic of an infectious disease, but the metabolic diseases and bloat were distributed between herds in precisely the same way, which implies that the unknown factors tending to cause a high incidence of these diseases were distributed over relatively few farms.

The survey data relevant to infertility are briefly discussed.

The information obtained about cows culled from the herds was used to show some of the factors affecting seasonal changes in the size of the national herd, and to estimate the shortening of the productive life and depreciation in the market value of diseased cows.

Although there are many reasons why the earlier data summarised by the Gowland Hopkins Committee are not strictly comparable with the data from this survey, possible comparisons suggest that the health of dairy herds in the last 30 years has greatly improved and has allowed a greater rate of culling for low milk yield and an increase in the numbers of cows reaching that rather nebulous period "old age".

- 12.19. (O'CONNOR, L. K.) & LIPTON, S. (1960). The effect of various sampling intervals on the estimation of lactation milk yield and composition. *J. Dairy Res.* **27**, 389-398.

The effect was studied of various sampling intervals on the accuracy of estimating lactation milk yield, fat yield, solids-not-fat (s.n.f.) yield, fat percentage and s.n.f. percentage.

The basic data consisted of daily milk, fat and s.n.f. yields for 18 lactations made by 12 Dairy Shorthorn cows. Estimates of the lactation yields and quality were obtained using 7-, 14-, 28-, 42-, 56- and 63-day sampling intervals, and were expressed as differences from the actual values.

Only with milk yield was there any effective bias in the estimates. This bias increased with increasing sampling interval.

The distributions of differences between estimated and actual values are presented. The error of estimation increased with increasing sampling interval.

Keeping in mind the comparatively small-sized sample used in the investigation, the results are discussed in the light of the purposes for which records are kept.

- 12.20. PATTERSON, H. D. & (LUCAS, H. L.) (1961). A catalogue of change-over designs. *Tech. Bull. N. Carolina agric. exp. Sta.*

This bulletin presents a comprehensive set of the available change-over designs which take account of first residual effects. The tables of designs are preceded by discussions of the choice and use of the designs. The bulletin also includes details and worked examples of the analysis in which additive constants are fitted for direct and first residual effects. Modified methods of analysis appropriate to some special situations are also described.

- 12.21. (PIZER, N. H., WRIGHT, H. A., CALDWELL, T. H., HARGRAVE, J., BURGESS, G. R., CORY, V.) & BOYD, D. A. (1961). A study of the peat fenlands with particular reference to potato manuring. *J. agric. Sci.* (In the press.)

Peat soils change gradually as a result of drainage and cultivation, losing depth from shrinkage, oxidation and blowing, changing in character through increases in mineral matter and "drumminess", and changing in productivity and manurial requirements. The sequence of changes was studied in the field and some stages distinguished which may be recognised quite simply from the texture of the ploughed layer. Texture is a field assessment of the type and condition of the peat and the proportion and nature of the mineral matter associated with it. The fenland soils have been classified as follows: (1) peat soils, (2) peaty mineral soils, (3) organic mineral soils, and (4) mineral soils. Further subdivision into textural classes depends on recognising the mineral combinations or fractions as in texturing mineral soils.

Analysis of samples of the ploughed layer in the laboratory showed that

organic matter or loss on ignition figures, expressed as a percentage of the oven-dried soil, can be used to recognise the textural groups, and use is made of this in considering those earlier experiments for which organic matter figures could be calculated.

Thirty-eight experiments of the standard $3 \times 3 \times 3$ design, testing the effects of N, P and K fertilisers on maincrop potatoes, were made in the peat fenlands in the years 1952-56. The main influence of the kind of soil was on total yield and response to potassium. The mean yields were considerably less on the peat soils than on the peaty mineral and organic mineral soils. The responses to N were substantial in each soil group, but less on the peats than on the peaty mineral and organic mineral soils. The responses to N were surprising in view of the organic nature of the soils. All soil groups responded better to P than to N, and past generous manuring with superphosphate seemed to have little effect on response. Responses to K were highest on the peats and fell off progressively through the peaty mineral and organic mineral soils; on soils containing relatively little organic matter and a correspondingly high proportion of clay minerals, there was evidence that potash caused a small but definite decrease in yield. Nitrogen and potash responses were greatest in 2 years with little blight and least in 2 years when blight was severe.

Tuber size was lessened by the application of phosphate, moderate dressings having much the same effect as large ones; nitrogen and potash had little effect. Growth of tops was greatly stimulated by phosphate, the effect being most noticeable during June and decreasing afterwards; the nitrogen had little effect during June, but substantially increased top growth during July and early August; the effect of potash was small.

The value of soil analysis in predicting responses to phosphate and potash is discussed. Recommendations are made for the manuring of potatoes on peat fenland soils.

12.22. POTATO MARKETING BOARD, ROTHAMSTED EXPERIMENTAL STATION & THE NATIONAL INSTITUTE OF AGRICULTURAL ENGINEERING (1960). *Report on the survey of maincrop potatoes. 1958: Potato Marketing Board Report.*

A survey of 971 farms was done in 1958 to provide information on current farm practices for maincrop potatoes, with particular reference to the use of machinery. Information is given on cultivations, planting and harvesting methods, seed types and rates, fertiliser and spraying practice, and storage, making comparisons with previous survey results.

Three-quarters of the maincrop acreage was machine-planted in 1958, compared with a third in 1948, but the total acreage declined by almost half during this decade. There has been a trend towards deeper ploughing, and more than a third of the 1958 acreage was ploughed to a depth of 11 inches or more. 57% of the acreage was planted with certified seed, 41% with once-grown seed and 2% with seed grown twice or more. In most parts of England the proportion of certified seed was rather smaller than in 1948. Seed rates had changed little and were heavier for certified than uncertified seed.

In 1958, a severe blight year, half the acreage was sprayed, usually with copper-based chemicals, and almost a quarter of the treated acreage was sprayed from the air. 58% of the acreage was lifted by spinners, 33% by elevators and only 5% by complete harvesters. Three-quarters of the farms depend on seasonal labour for picking.

The survey estimate of average yield, based on lifting random lengths of row, was 7.7 tons of sound potatoes/acre, compared with an independent Ministry of Agriculture estimate of 7.1 tons/acre based on crop reports.

12.23. SIMPSON, H. R. (1961). The analysis of survey data on an electronic computer. *J. R. statist. Soc. A.* (In the press.)

This paper describes the lessons learnt from experience of programming survey analyses for the Rothamsted computer. The difficulties of handling large quantities of data, especially on small computers, are discussed, and a general programme for the analysis of surveys is described.

- 12.24. (TANNER, J. M.), HEALY, M. J. R., (WHITEHOUSE, R. H. & EDGSON, A. C.) (1959). The relation of body build to the excretion of 17-ketosteroids and 17-ketogenic steroids in healthy young men. *J. Endocrinol.* **19**, 87.

The excretions of 17-ketosteroids, 17-ketogenic steroids and creatine from 101 medical students were measured and compared with assessments of body build based on anthropometric measurements, somato typing and on limb widths of fat, muscle and bone. Week-to-week variations in individuals' excretions were taken into account in assessing relationships. The main conclusions drawn are:

1. Individual level of 17-KS and 17-KGS excretion are inversely related, especially when allowance is made for body size.
2. 17-KS excretion is related to body weight, mesomorphy and muscle width.
3. 17-KGS excretion is related to weight and height, via the widths and lengths of the limb bones. There is no relation with muscle width or with subcutaneous fat.

The implications of these conclusions are discussed.

- 12.25. YATES, F. (1961). Marginal percentages in multiway tables of quantal data with disproportionate frequencies. *Biometrics*, **17**. (In the press.)

When multiway tables of quantal data are analysed by transforming the percentages and fitting constants to the transformed variate by the method of maximum likelihood, direct inverse transformation of the values of the fitted constants gives percentages which may deviate widely from those observed. The reasons for this are explained, and methods are given for obtaining correct percentages.

- 12.26. YATES, F. & SIMPSON, H. R. (1960). A general programme for the analysis of surveys. *Comput. J.* **3**, 136-140.

A programme for the analysis of surveys, written for the Elliott 401, is described. In spite of the small size of the machine, it has been possible to develop a general programme which can perform the very varied operations that are commonly required in the analysis of survey material.

- 12.27. YATES, F. & SIMPSON, H. R. (1961). The analysis of surveys: processing and printing of the basic tables. *Comput. J.* (In the press.)

This paper describes the second part of a general programme for the analysis of surveys, written for the Elliott 401 computer. Part 2 of the programme processes and prints the tables generated by Part 1, which was described in 12.26.

Dunholme Field Station

GENERAL PAPERS

- 16.1. ADAMS, S. N. (1960). Sugar-beet fertiliser experiments in 1959. *Min. Agric. Sugar Beet Res. & Educ. Comm. Pap.* 569.
- 16.2. ADAMS, S. N. (1960). Fertiliser trials with sugar beet. 1. The "Types of Nitrogen" experiments. *Brit. Sugar Beet Rev.* **28**, 175-176.
- 16.3. ADAMS, S. N. (1960). Sodium and sugar beet. *Brit. Sugar Beet Rev.* **29**, 18.
- 16.4. ADAMS, S. N. (1960). The effect of different forms of nitrogen on sugar beet, and the value of late top-dressing. *Rep. 23rd Winter Congr. int. Inst. Sugar Beet Res.*, Brussels 1960, 283-288.

ABSTRACTS OF PAPERS

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- 16.5. BYFORD, W. J., DUNHAM, E. C., DUNNING, R. A., HEATHCOTE, G. D., HULL, R., & WINDER, G. H. (1960). Sugar-beet disease investigations, 1959-60. *Min. Agric. Sug. Beet Res. & Educ. Comm. Pap.* 575.
- 16.6. DUNNING, R. A. (1960). Virus yellows: the need to look ahead. *Brit. Sug. Beet Rev.* **29**, 37-40.
- 16.7. DUNNING, R. A. (1960). Pest populations, especially virus vectors, and productivity of sugar beet. XI International Congress of Entomology, Vienna, August, 1960.
- 16.8. HULL, R. (1960). A new factor in sugar-beet growing. *Brit. Sugar Beet Rev.* **28**, 113-132.
- 16.9. HULL, R. (1960). Sugar-beet yellows in Great Britain, 1959. *Plant Path.* **9**, 151-152.

RESEARCH PAPERS

- 16.10. ADAMS, S. N. (1961). The effect of time of application of phosphate and potash on sugar beet. *J. agric. Sci.* **56**, 127-130.

Twenty-nine experiments on sugar beet in 1957-59 compared ploughing-down of phosphate and potash in the previous autumn with spring application before the seedbed preparations.

On average, spring application gave a higher yield of sugar and tops than ploughing-down both in the wet summers of 1957 and 1958 and in the dry summer of 1959.

Plants on plots where fertiliser was broadcast in spring usually grew quicker early in the season, which is probably why this method of application was superior. In 1959, with a starter dose of phosphate and potash in the seedbed, ploughing-down was almost as effective as broadcasting.

- 16.11. ADAMS, S. N. (1961). The effect of sodium and potassium on sugar beet on the Lincolnshire limestone soils. *J. agric. Sci.* **56**. (In the press.)

Seventeen experiments in 1957-59 on the Lincolnshire limestone soils tested the response of sugar beet to 1.5 cwt. K_2O /acre as muriate of potash and its chemical equivalent of sodium chloride (1.8 cwt./acre). Average response of sugar beet to sodium was higher than to potassium, especially in the wet summer of 1958. There was a negative interaction between sodium and potassium.

Although trials were confined to similar soils, the response to fertiliser varied widely in different experiments. Exchangeable soil potassium extracted by *N/10*-nitric acid, although not by *N*-ammonium nitrate, predicted potassium response to some extent. There was a close correlation between response to sodium and to potassium, so soil potassium also predicted response to sodium. Exchangeable soil sodium did not predict the response to fertiliser.

The rate of sodium chloride used never visibly impaired germination. On average, sodium increased plant population, and the increases in plant population were significantly correlated with response to sodium and to the superiority of sodium over potassium. On some fields, weed control by sodium chloride may account for its raising sugar yield more than potassium.

- 16.12. ADAMS, S. N. (1961). The effect of sodium and potassium fertiliser on the mineral composition of sugar beet. *J. agric. Sci.* **56**. (In the press.)

This paper summarises work by the late J. B. Hale, who analysed plants from salt and potash fertiliser trials at Rothamsted, harvested at intervals throughout the growing seasons of 1942 and 1943, for N, K, Na, Ca, Mg and Mn.

The uptake of nutrients is discussed with respect to field methods of fertiliser application.

Salt increased beet yield in both years, but it did not act by mobilising soil potassium reserves and increasing the potassium status of the plant. Potash fertiliser, although increasing the potassium status of the plant, did not increase yield. Sodium and potassium were differently distributed in the plant. At harvest, only 6% of the plant's sodium content was in the root compared with 33% of the potassium. The potassium, but not the sodium, content of the petiole was higher than that of the lamina until the end of August. Sodium thus is a nutrient for beet and not a potassium substitute.

- 16.13. DUNNING, R. A. (1960). Seed and soil treatment with systemic insecticides for control of beet pests, especially vectors of virus yellows. *Rep. 23rd Winter Congr. int. Inst. Sugar Beet Res.*, Brussels, 1960, 429-433.

When used as seed dressings, the systemic insecticides phorate (diethyl ethylthiomethyl dithiophosphate) and "Disyston" (diethyl ethylthioethyl dithiophosphate) control foliage pests after sugar-beet seedlings emerge, but, at rates of dressing necessary for useful insecticidal persistence, they often damage the plants. Granular formulations, applied to the soil or foliage, are not so phytotoxic and their insecticidal effect persists.

- 16.14. DUNNING, R. A. (1961). Mangold fly: its incidence, economic importance and control. *Plant Path.* **10**, 1-9.

Attacks by mangold fly are most frequent in coastal regions and in the North and West, and occurred especially in 1947 and 1954-55. Insecticides are recommended on the results of comparative tests. The use of materials that are also aphicidal is advised when aphids are present, especially in areas where virus yellows is important. Yield trials show that control of mangold fly is economic in England only when backward beet are severely infested.

- 16.15. HULL, R. (1960). The selection of sugar-beet varieties for tolerance to virus yellows. *Rep. 23rd Winter Congr. int. Inst. Sugar Beet Res.*, Brussels, 1960, 407-417.

Lines of sugar beet that tolerate yellows were obtained by self-pollinating plants which had been selected for yield from plots of commercial varieties with yellows. They gave up to 20% more sugar yield than commercial varieties in the field when yellows was severe, but less when free from yellows. A hybrid between two tolerant lines had a greater leaf area and net assimilation rate than variety Sharpes E when infected with yellows. Yellows decreased the yield of the hybrid by 35% and of Sharpes by 65%. Most roots of Sharpes E with yellows weighed about 400 g., but occasional roots weighed over 1,000 g., so that the distribution diagram of root weights was asymmetric. The root weights of the hybrid when infected had a more normal distribution, with the mode about 700 g. and the maximum 1,500 g.

Soil Survey of England and Wales

- 17.1. *The soils and land use of the district around Rhyl and Denbigh.* (Sheets 95 and 107). London: H.M. Stationery Office, 1960.
- 17.2. *Soil map of Beaumaris*, Sheet 94 (3rd Edn.). Southampton: Ordnance Survey, 1960.
- 17.3. CRAMPTON, C. B. (1960). Petrography of the Mesozoic succession of South Wales. *Geol. Mag.* **97**, 215-228.

The heavy mineral suites of the Trias, Rhaetic and lowest zones of the Lower Lias in the Vale of Glamorgan are described. The northerly coastline of the Mesozoic sea, roughly coincident with the present periphery of the Coalfield, consisted mainly of Carboniferous Limestone and, in places, the Old Red Sandstone and Millstone Grit. The assemblage at any point in the littoral zone was largely determined by the nature of the outcropping rocks of the

coast, the derivation of detritus being very localised. In this zone some degree of gravity sorting of the detritals occurred, implying a steeply inclined coastal sea-bed. An off-shore current carried detritus from the Armorican land-mass of Brittany and granite of South-West England to this area where the detritals were dispersed thinly throughout the locally derived sediment.

- 17.4. CRAMPTON, C. B. (1960). Analysis of heavy minerals in the Carboniferous Limestone, Millstone Grit and soils derived from certain glacial gravels of Glamorgan and Monmouth. *Trans. Cardiff Nat. Soc.* **87**, 13-22.

An attempt was made to amplify the knowledge of the heavy mineral assemblages of local rock strata by examining the Carboniferous Limestone and Millstone Grit as a prelude to investigating the mineral suite of drift soils developed on glacial sands and gravels in Glamorgan and Monmouthshire. The soil profile shows no marked change throughout the area investigated. Material from the Coalfield constitutes an important part of the parent material, and the Irish Sea Drift a small but consistent element. To the east of the area material from the Old Red Sandstone has also been incorporated, and to the west material from the Millstone Grit, and to a lesser extent, from the Carboniferous Limestone. Local ice flows travelling across the Coalfield from the north would produce these mixed superficial deposits.

- 17.5. CRAMPTON, C. B. & WEBLEY, D. (1960). The correlation of pre-historic settlement and soils in the Vale of Glamorgan in III Archaeology and Art. *Bull. of the Board of Celtic Studies*, **18**, 387-396.

Prehistoric settlement in the Vale of Glamorgan has been correlated, age by age, with the distribution of various soils mapped during routine soil survey of the County of Glamorgan. Neolithic and Bronze Age man preferred the freely drained soils on the various limestones. The evidence suggests that Neolithic man placed his burial mounds as far as possible from the settlement areas, and near the boundary of the free draining soils with the impeded soils. The tombs of the Middle Bronze Age are, however, more dispersed over the limestone outcrop; some must have been near the settlements. Migration on to the freely drained sandy soils over Glacial drift becomes greater during the Bronze Age, but it was only during the Iron Age that these soils were extensively exploited. It remained for the Romans to exploit the heavier impeded soils, previously ignored.

- 17.6. MACKNEY, D. (1960). Soils and soil maps. *N.A.A.S. quart. Rev.* no. **46**, 47-52.

A semi-popular account of soil morphology and the preparation of soil maps with some explanation of their uses and a plea for co-operation in deducing productivity ratings of soils.

Library

- 18.1. BOALCH, D. H. (1961). Current literature on agriculture in tropical and sub-tropical countries. *Brit. Book News*, **245**, 1-6.