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SCIENTIFIC PAPERS

PLANT GROWTH, AND ACTION OF MANURES

(Departments of Botany, Chemistry, Insecticides and Fungicides; Field Experiments Section; Woburn Experimental Station; and Imperial College Staff.)

(a) PLANT GROWTH

- I. E. J. RUSSELL and D. J. WATSON. "*The Rothamsted Field Experiments on Barley 1852-1937. A. The Older Rothamsted Experiments.*" *The Empire Journal of Experimental Agriculture*, 1938, Vol. VI, pp. 268-292.
- II. E. J. RUSSELL and D. J. WATSON. "*The Rothamsted Field Experiments on Barley 1852-1937. Pt. II. Effects of Phosphatic and Potassic Fertilizers; Deterioration under Continuous Cropping.*" *The Empire Journal of Experimental Agriculture*, 1938, Vol. VI, pp. 293-314.

A review and summary of the results of experiments on barley carried out at Rothamsted, Woburn and other centres from 1852 to 1937.

Parts I and II deal with factors which affect yield, and Part III (in the press) with the factors which determine the quality of the grain.

In Part I, it is shown that the relation between the yields of grain and straw is very close, so that the variation in the ratio of grain to total produce is small. Further discussion is therefore confined to the yield of grain. An account is given of the effects of soil type, seasonal climatic factors and nitrogenous fertilizers. Different forms of nitrogenous fertilizer are compared, and the effects of rainfall and of time of sowing on the response to added nitrogen are discussed.

In Part II phosphatic and potassic fertilizers are considered. It is shown that these are usually of less importance than nitrogenous fertilizers. Other factors discussed are:—farmyard manure; soil reaction; fallowing; deterioration of yield under continuous cropping with barley; undersowing with clover.

- III. D. J. WATSON and E. C. D. BAPTISTE. "*A Comparative Physiological Study of Sugar-beet and Mangold with respect to Growth and Sugar Accumulation. I. Growth Analysis of the Crop in the Field.*" *Annals of Botany*, 1938, New Series, Vol. II, pp. 437-480.

A study was made of the growth of sugar-beet and mangold sown on six occasions at intervals of a fortnight in 1934. Samples were taken at fortnightly intervals to determine (1) dry weight of lamina, petiole and root; (2) water content of lamina, petiole and root; (3) leaf area per plant.

Sugar-beet ultimately attained a greater dry weight than mangold, the difference being mainly in the leaves. The dry weight of lamina and petiole continued to increase for a longer period in sugar-beet than in mangold.

Later sowing decreased the dry weight of root at all sampling times, but in the later stages of growth it caused a marked increase in lamina and petiole dry weights.

The water content of mangold was very much greater in all parts of the plant than in sugar-beet. Later sowing caused an increase of water content.

The number of leaves per plant was greater in sugar-beet than in mangold owing to a slightly higher rate of production and a lower death rate. Later sowing increased the rate of production. The rate of leaf production was correlated with mean temperature, Q_{10} being 3.1.

The variation of leaf area per plant was similar to that of lamina dry weight. The effect of sowing date on leaf area was greater than on leaf weight.

The Relative Growth Rate was slightly greater in sugar-beet than in mangold; it decreased throughout the growth period, falling eventually to zero.

Later sowing increased the Relative Growth Rate in the early stages, due to an increase in the Leaf Weight Ratio ; Unit Leaf Rate was unaffected by date of sowing.

- IV. D. J. WATSON and I. W. SELMAN. "*A Comparative Physiological Study of Sugar-beet and Mangold with respect to Growth and Sugar Accumulation. II. Changes in Sugar Content.*" *Annals of Botany*, 1938, New Series Vol. II, pp. 827-846.

An account is given of the changes during growth in the sucrose and reducing sugar content (expressed per 100 g. of dry matter and per 100 g. of water) of the lamina, petiole, and root of sugar-beet and mangold sown on six occasions in 1934.

Sugar-beet had a higher content of both sucrose and reducing sugars than mangold, except that the sucrose content of the lamina was almost the same in the two plants, and in the root the reducing sugar content was greater in mangold. In general, both the sucrose and reducing sugar content of all parts of the plant increased steadily with time.

The sucrose content increased through the plant in the direction from lamina to root. The reducing sugar content was highest in the petiole, and was greater in the lamina than in the root. It is pointed out that this does not necessarily imply that translocation takes place against a gradient of sugar concentration, for gradients falling in the direction of movement may exist in the conducting tissues, which are masked in the mass analyses of lamina, petiole, and root. The data give little direct evidence on the mechanism of translocation, but they serve to illustrate some fallacies in the arguments of Davis, Daish, and Sawyer for the view that sucrose in the leaf is an immediate product of photosynthesis and that carbohydrate is translocated as hexose.

There is no clear distinction in the root between a phase of growth and a phase of sucrose storage, for the very young roots have a high sucrose content. Growth and accumulation of sucrose proceed together.

On the mean of all sampling times, a significant increase of sucrose content was found in the leaf lamina, between 10 a.m. and 4 p.m. The corresponding increase in reducing sugar was smaller and not significant. The average changes during the day in the sugar content of the petiole were almost the same as those of the leaf lamina, but were not significant. There was no indication of any diurnal variation in the root.

Later sowing caused an increase in the reducing sugar content and, to a less extent, in the sucrose content of the leaf lamina, in the later stages of growth. The reducing sugar content of the petiole was similarly affected, but the sucrose content of petiole and root was always depressed by later sowing. The reducing sugar content of the root was also slightly decreased. These results suggest that the effect of later sowing, previously demonstrated, in increasing the size and weight of the leaves, was caused by a restriction of the movement of carbohydrate out of the leaf, rather than by an increased ability of the leaf to utilize assimilate in growth.

Later sowing depressed the total yield per acre of sucrose in the root.

- V. F. J. RICHARDS. "*Physiological Studies in Plant Nutrition. VIII. The Relation of Respiration Rate to the Carbohydrate and Nitrogen Metabolism of the Barley Leaf as Determined by Phosphorus and Potassium Supply.*" *Annals of Botany*, 1938, New Series, Vol II, pp. 491-534.

Barley was grown in sand culture at three levels of phosphorus nutrition. In three other series phosphorus and potassium were reduced proportionately.

Very considerable treatment differences were obtained in growth rate, final yield and weight of corresponding leaves ; these being almost entirely due to phosphorus and nearly independent of variation in potassium supply at any one phosphorus level.

Water content differences were comparatively slight.

Changes in respiration rate undergone during the first few hours in the dark are described and the results of Gregory and Sen (1937) confirmed.

Respiration rate was greatly reduced by phosphorus deficiency, the change with supply being greatest at comparatively high levels. When phosphorus

and potassium were simultaneously proportionally reduced, the fall in respiration was at first more gradual than when phosphorus alone was altered, but at lower levels the resultant change was greater.

Progressive phosphorus deficiency led to progressive reduction in protein content and progressive and considerable increase in amino nitrogen.

Total sugars and sucrose were in general reduced by phosphorus deficiency, while reducing sugar was increased.

Respiration was generally closely related to nitrogenous substances in the series with high potassium and phosphorus supply. As the level of phosphorus supply falls the content of reducing sugar becomes of increasing importance which is interpreted as evidence for hexose as substrate and the importance of phosphate for its breakdown.

- VI. W. E. BRECHLEY. "Comparative Effects of Cobalt, Nickel and Copper on Plant Growth." *Annals of Applied Biology*, 1938, Vol. XXV, pp. 671-694.

A general review is given of the distribution and the physiological importance of nickel and cobalt, in relation to plants and animals.

Experiments on barley and broad beans were carried out in water cultures with the sulphates and chlorides of cobalt, nickel and copper. In every case a range of low concentrations did little or no damage, but toxic action occurred abruptly above a concentration which varied with the species and with the compound. With barley, copper was the most poisonous element in either compound, but the differences were not striking. Low concentrations of the sulphate were innocuous, but parallel low strengths of the chloride caused a slight significant depression in growth. With broad beans, cobalt was much more poisonous than either nickel or copper, particularly with the sulphate. No slight depression with low concentrations of the chloride was noticeable with this species.

The morphological response to toxicity varied with the element concerned. Copper, in poisonous strengths, caused shortening and "bunching" of barley roots, whereas nickel and cobalt permitted the growth of elongated roots of a very attenuated nature. The individuality of plant response to poison was frequently shown by the great variation in growth in the borderline concentrations just below those which caused marked depression of growth.

(b) ACTION OF MANURES

- VII. H. H. MANN. "The Weed Herbage of a Slightly Acid Arable Soil." *Journal of Ecology*, 1939, Vol. XXVII, pp. 89-113.

The weed herbage was studied on a light sandy loam of slightly acid character which has been under continuous wheat or barley cropping for over fifty years. The several plots had various manurial treatments to 1926 and no manures since that date. A fallow taken in 1934 and 1935 enabled the general character of the weeds to be determined during the season.

With most of the important annual weeds in the soil, roughly half the year's growth of plants germinated before the end of April. This does not apply to individual weeds as the dominant one (*Spergula arvensis*) germinates at any time in the year, while some of the others, notably *Polygonum aviculare* (March to May), *Gnaphalium uliginosum* (June to September) and *Chenopodium album* (May and June) were very seasonal.

A single year's fallow, even when accompanied by frequent cultivations, is not very effective in getting rid of the annual weeds. Two years' fallow brings about, however, a fairly large reduction, except with *Stellaria media* and *Poa annua*, neither of which appeared to be appreciably altered in amount.

Acidity of the soil induced by previous manuring with sulphate of ammonia, had a very great influence on the weed herbage, and when the pH value was lower than 5.0, the annual plants consisted almost entirely of *Spergula arvensis*, with a small amount of *Polygonum aviculare* and *Poa annua*. *Matricaria inodora*, though an acid loving weed, disappeared almost entirely when the pH value was less than 5.4, but was also reduced in amount when the pH value was greater than 5.8. *Polygonum aviculare* and *Poa annua* are by far the least sensitive to changes in acidity of all that were found on the plots studied.

The effect of long continued application of mineral manures was very small on the number of plants per unit area, except in the case of *Vicia hirsuta*,

which appeared as a serious weed only in the plots which had received mineral manures or farmyard manure, and then only when the pH value was over 5.6. The annual addition of farmyard manure for fifty years left a legacy of an increased amount of most of the weeds.

The effect of lime on the weed herbage is almost entirely governed by the change in acidity thereby induced. The lime did not appear to have a specific effect on any of the annual weeds examined.

The perennial weeds which tended to take possession of the plots were two "twiches," namely *Holcus mollis* and *Agrostis stolonifera*, which became serious in the more acid plots, while the more usual twitch (*Agropyrum repens*) was wholly absent in this sandy acid land. *Rumex acetosella* was common on the more acid plots and could not be got rid of even by a two years' fallow. *Equisetum arvense* occurred largely, though there was no sign of wetness anywhere in the field, and seemed to be rather encouraged by the fallowing of the land. *Convolvulus arvensis* only occurred in plots which had had mineral manures or farmyard manure in the previous half century, but its amount was hardly affected by even a two years' fallow.

- VIII. J. T. MARTIN, H. H. MANN and F. TATTERSFIELD. "The Manurial Requirements of *Pyrethrum* (*Chrysanthemum cinerariaefolium* Trev.)." *Annals of Applied Biology*, 1939, Vol. XXVI, pp. 14-24.

A small field experiment upon the manurial requirements of the insecticidal pyrethrum plant, grown upon sandy soil of low fertility, is described. Lime had the effect of producing slight, but not significant, increases each year in the yield of flowers and their content of the pyrethrins, and decreased the percentages of plant failures in the fourth and fifth years of the experiment. There was a significant depression in the yield of flowers in the year after the single application of double dressings of the manures, but no effect in later years. The yearly application of moderate dressings of manures gave significant increases in the yield of flowers in the second and fifth years, and significant increases in the pyrethrin I content of the flowers in the fourth and fifth years of the experiment.

- IX. H. H. MANN. "Investigations on Clover Sickness." *Journal of Agricultural Science*, 1938, Vol. XXVIII, pp. 437-455.

If a clover sick soil be defined as one on which a normal crop of clover cannot be grown, but on which only small dwarfed plants are produced, the clover sickness can be found in the absence of the usual fungi to which it has been attributed, and also in the absence of the eelworm (*Anguillulina dipsaci*) which generally accompanies it.

In the particular soil examined, no manuring with lime, potash, or phosphates, or with easily available nitrogen in the form of potassium nitrate had any considerable effect in enabling good growth of clover to be obtained. Two methods, however, were capable of temporarily giving good crops. The first was the heating of the moist soil to a temperature of 60 to 70° C. for 1 to 2 hours. The effect of this treatment, however, passed off in a few months after one or two crops of clover had been obtained. The second method was the application of a very large dressing of farmyard manure. This was at first quite effective, but the quantity needed was not such as could be used in practice. Where nearly 10 per cent. of the weight of the soil was added in the form of wet farmyard manure, the effect continued even after four successive crops of clover had been grown: where 3 per cent. of the soil weight was added, the benefit very rapidly passed away after the second crop.

- X. E. M. CROWTHER and R. G. WARREN. "Report on Pot Culture, Laboratory Work and Other Investigations." Appendix I to the Fifteenth Report of the Permanent Committee on Basic Slag, Ministry of Agriculture, 1937, pp. 4-11.

In pot cultures four types of basic slag were compared for perennial ryegrass and turnips on an acid Scottish soil and on a neutral sand-bentonite mixture with two depths of incorporation of the basic slags. The turnips in spite of damage by pests responded to slags on both soils, but the ryegrass

responded only on the artificial soil. The fact that rye-grass grew well on a soil on which turnips had failed completely from phosphate shortage in the field in the previous season suggests that some of the poor residual effects observed in field experiments are due to the ability of other crops to utilise soil phosphates which are not available to swedes. In the pot experiments in the soil but not in the sand the turnips gave better results when the slags were concentrated in a narrow band than when they were distributed more diffusely.

In conjunction with the Forestry Commission two experiments were laid down on young trees in Scotland to test three rates of application of three slags and mineral phosphate.

- XI. E. M. CROWTHER and R. G. WARREN. "*Report on Pot Culture, Laboratory Work and Other Investigations, 1937.*" Appendix I to the Sixteenth Interim Report of the Permanent Committee on Basic Slag, Ministry of Agriculture, 1939, pp. 4-9.

The pot experiments of the previous year were continued with clover, perennial rye-grass and timothy. In the sand cultures, from which about half of the citric soluble phosphoric acid of the slags had been removed in the previous year's crops, the clover failed and the two grasses did not grow well. In the soil all three crops grew well but the responses to basic slag residues were so small that it was not possible to differentiate between slags or between the responsiveness of the different crops.

Laboratory extractions under controlled pH values brought out the unexpected result that the relative solubilities of two medium soluble slags were different in citric acid and in other acids at the same pH value.

- XII. E. M. CROWTHER (with D. N. McARTHER). "*Report on Field Experiments in 1936.*" Appendix II to Fifteenth Interim Report of the Permanent Committee on Basic Slag, Ministry of Agriculture, 1937, pp. 12-22.

Four field experiments were conducted on swedes to compare two rates of application of three less soluble types of slag with four rates of application of a high-soluble slag. The yields from the less soluble slags were generally similar to those from high soluble slag supplying equal amounts of citric-soluble phosphoric acid. The phosphoric acid contents of the dry swedes were increased considerably by the higher rates of application of the more soluble slags and this allowed comparisons of the slags to be made over a much wider range than was possible from the yields alone.

- XIII. E. M. CROWTHER (with D. N. McARTHER). "*Report on Field Experiments in 1937.*" Appendix II to the Sixteenth Interim Report of the Permanent Committee on Basic Slag, Ministry of Agriculture, 1939, pp. 10-22.

Five experiments similar to those of 1936 again gave very steep response curves to basic slag, one-eighth of the customary dressing of high-soluble slag doubling the yield of swedes. Such results emphasise the importance of working well below the upper limit of yield in comparing the availabilities of different slags. The results were generally related to the amounts of citric soluble phosphoric acid supplied, except that those from the more soluble of the two medium-soluble slags were definitely better than would have been expected on this basis. This failure of the citric acid method was far more striking than in any of the three preceding years.

STATISTICAL METHODS AND RESULTS

(Department of Statistics ; and Field Experiments Section)

(a) THEORETICAL

- XIV. F. YATES. "*An Apparent Inconsistency Arising from Tests of Significance Based on Fiducial Distributions of Unknown Parameters.*" Proceedings of the Cambridge Philosophical Society, 1939, Vol. XXXV, Part IV.

The problem of testing whether the means of two samples are significantly different, when there is no reason to suppose that the variances of the observations on which the means are based are equal, presents certain features which do not arise in other tests of significance.

Behrens and Fisher have proposed an exact test based on the fiducial distribution of the ratio of the variances of the two sets of observations, which at first sight appears to give rise to certain inconsistencies. The cause of these apparent anomalies is explained and it is shown that the criticisms based on them are invalid, being due to (a) neglect of the relevant information provided by the estimated values of the variances, and (b) an insufficient appreciation of the fiducial basis of all tests of significance (including the ordinary t-test) on small samples.

The problem of testing the weighted mean of the means of two sets* of observations concerning whose relative accuracy no prior knowledge is available is shown to be similar to that of testing the difference of the means of two samples.

- xv. F. YATES. "*Tests of Significance of the Differences between Regression Coefficients Derived from Two Sets of Correlated Variates.*" Proceedings of the Royal Society of Edinburgh, 1939, Vol. LIX, pp. 184-194.

Tests of significance of the differences of regression coefficients derived from two sets of correlated dependent and independent variates are described. The necessary computations are reduced to a systematic and easily calculable form, and are illustrated by a numerical example.

- xvi. F. YATES. "*Orthogonal Functions and Tests of Significance in the Analysis of Variance.*" Supplement to the Journal of the Royal Statistical Society, 1938, Vol. V, pp. 177-180.

In many types of statistical analysis based on the method of least squares, it is necessary to test the significance of one group of effects while admitting the possible existence of other groups of effects.

In the present paper explicit proof is given of the procedure adopted for such tests of significance. The general properties of orthogonal functions are also described.

- xvii. F. YATES. "*The Adjustment of the Weights of Compound Index Numbers Based on Inaccurate Data.*" Journal of the Royal Statistical Society, 1939, Vol. CII, pp. 285-288.

The problem of choosing the weights of the components of compound index numbers based on inaccurate data is discussed. It is shown that a process analogous to that adopted for the formation of a discriminant function will give the set of index numbers agreeing most closely with the entities they are intended to represent.

- xviii. W. G. COCHRAN. "*The Omission or Addition of an Independent Variate in Multiple Linear Regression.*" Supplement to the Journal of the Royal Statistical Society, 1938, Vol. V, pp. 171-176.

If tests of significance of the regression coefficients are required in a multiple regression, the normal equations are usually best solved by finding first the components c_{pq} of the inverse matrix. When it is desired to omit or to add one or more independent variates after the original regression equations have been solved, the new c 's and regression coefficients may easily be calculated from the original c 's and regression co-efficients. A numerical example of the addition of an independent variate is given to illustrate the computations.

- xix. W. G. COCHRAN. "*An Extension of Gold's Method of Examining the Apparent Persistence of One Type of Weather.*" Quarterly Journal of the Royal Meteorological Society, 1938, Vol. LXIV, pp. 631-634.

If a meteorological event is classified into two types only, for instance wet or dry months, a tendency towards persistence of the same type of weather may be tested by examining the distribution of lengths of runs of the same type. Gold's formula for the expected number of runs of length r from m events is extended to the case in which the probabilities of the two events are unequal. A simple test of significance of persistence is found by classifying the data in a 2×2 contingency table, according to the results at the current and previous trials.

(b) DESIGN AND ANALYSIS OF EXPERIMENTS

- XX. F. YATES. "*The Recovery of Inter-block Information in Variety Trials Arranged in Three Dimensional Lattices.*" *Annals of Eugenics*, 1939, Vol. IX, pp. 136-156.

The quasi-factorial and incomplete block designs, as originally put forward, although in general considerably more efficient than designs involving the use of controls, had the defect of being *less* efficient than ordinary randomized blocks if the reduction in variability resulting from the use of the smaller blocks was in fact small. This was a consequence of the fact that certain of the varietal (or treatment) comparisons were confounded with block differences, and the information contained in the inter-block comparisons was wholly discarded.

In the present paper an account is given of the method of estimating the relative accuracy of these comparisons, and of recovering the information contained in them. Only the case of the three dimensional lattice is discussed here. It is proposed to deal with the other types of design in subsequent papers.

The procedure consists of so arranging the analysis of variance that an estimate of the inter-block variance is provided, freed from varietal effects, and then calculating adjustments to the varietal means such that the inter and intra-block comparisons are correctly weighted according to their relative accuracy.

The computations are fully illustrated by a numerical example. It is shown that the amount of computation required for the full analysis is scarcely greater than that required for the complete elimination of block effects, which was the method of analysis originally proposed.

With this modification the efficiency of these designs is shown to be always greater than that of ordinary randomized blocks, except for the limiting case when there is no reduction of variance due to the use of the smaller blocks: in this case a small amount of information is lost due to inaccuracies of weighting, but in general this loss is quite trivial.

It is also pointed out that it is quite legitimate to analyse the results of a quasi-factorial experiment as if it were an experiment arranged in ordinary randomized blocks. This is a valuable property of the designs, since it enables subsidiary measurements which are unlikely to be much affected by block differences, or for which high accuracy is not required, to be abstracted with a minimum of computation.

- XXI. F. YATES. "*The Comparative Advantages of Systematic and Randomized Arrangements in the Design of Agricultural and Biological Experiments.*" *Biometrika*, 1939, Vol. XXX, pp. 440-469.

The recent claims advanced in favour of systematic arrangements by Gosset ("Student") and others are examined. The conclusion is reached that in cases where Latin square designs can be used, and in many cases where randomized blocks have to be employed, the gain in accuracy with systematic arrangements is not likely to be sufficiently great to outweigh the disadvantages to which systematic designs are subject. In particular the available evidence, though not conclusive, indicates that the half-drill strip arrangement, which Gosset particularly favoured, is likely to be somewhat less accurate than suitable random arrangements occupying the same plots. On the other hand, systematic arrangements may in certain cases give decidedly greater accuracy than randomized blocks, but it appears that in such cases the use of the modern devices of confounding, quasi-factorial designs, or split plot Latin squares, which are much more satisfactory statistically, are likely to give a similar gain in accuracy.

As an example the uniformity trial chosen by Barbacki and Fisher to demonstrate the defects of the half-drill strip arrangement is re-examined. It is shown that Gosset's criticisms of Barbacki and Fisher's work, though at first sight convincing, are not as conclusive as he supposed, and that in fact this particular trial provides a striking example of just those defects which have always been attributed to the half-drill strip method by its critics.

- XXII. F. YATES and R. W. HALE. "*The Analysis of Latin Squares when Two or more Rows, Columns, or Treatments are Missing.*" Supplement to the Journal of the Royal Statistical Society, 1939, Vol. VI, pp. 67-79.

Methods of analysing a Latin square with two or more missing treatments, rows or columns are described, and illustrated by an example.

Attention is drawn to a special type of incomplete square, introduced by Youden, which is capable of simple analysis. Youden squares provide valid experimental arrangements, which are likely to be of value in biological experiments and occasionally in variety trials.

The evaluation of the reciprocal matrix when redundant constants or regression coefficients are introduced into least square solutions is also discussed.

- XXIII. W. G. COCHRAN. "*Long-term Agricultural Experiments.*" Supplement to the Journal of the Royal Statistical Society, 1939, Vol. VI, Part II.

The various types of long-term experiment are described. The design of experiments on a single crop or on a fixed rotation of crops with fixed treatments is discussed and the statistical analyses are illustrated by numerical examples. Where treatments are applied at fixed intervals only, the residual as well as the direct effects can be assessed. The possibility of obtaining greatly increased accuracy on the residual effects by ensuring that the periods of the crops and treatment cycles are different is pointed out. The method of separating the direct and residual effects when the treatments rotate from plot to plot in successive years is examined and illustrated by a numerical example. The design of long-term experiments on the effects of different crop sequences and the advisability of including indicator crops are discussed. In conclusion, some practical considerations of importance are mentioned.

(c) ANALYSIS OF DATA

- XXIV. F. YATES and D. J. WATSON. "*Factors Influencing the Percentage of Nitrogen in the Barley Grain of Hoosfield.*" Journal of Agricultural Science, 1939, Vol. XXIX, pp. 452-458.

The effect of rainfall, sowing date and yield on the percentage of nitrogen in the barley grain of certain representative plots on Hoosfield is studied.

All these factors are shown to have marked effects. The farmyard manure plot differs from the others, both in mean percentage and in the effects of rainfall and yield.

Changes in variety appear to have had little influence, but there is a progressive decrease in the percentage of nitrogen which cannot be accounted for by changes in any of the above factors.

Comparison is made with the results of the similar study on the permanent barley plots at Woburn.

- XXV. D. A. BOYD. "*Correlations Between Monthly Rainfall at Eleven Stations in the British Isles.*" Memoirs of the Royal Meteorological Society, 1939, Vol. IV, pp. 143-156.

The paper is based upon rainfall records for the months of January, April, July and October at eleven stations in the British Isles over the period 1870-1929.

The means, variances and covariances were computed. Percentage standard errors were obtained and mapped, the distribution proving similar in all months.

A correlation coefficient for each pair of stations in each of the chosen months was evaluated, and transformed to z . The value of z was dependent to a considerable extent on the inter-station distance and bearing. The linear regression of z on distance between stations was significant in each month, but the quadratic term was small and non-significant. The remaining two terms of the regression, associated with the bearing between pairs of stations, reached significance on only two occasions out of the possible eight; but, as a whole, they gave a reasonably coherent picture of monthly changes in the inter-station bearing at which correlation reached a maximum.

To account for such changes, and for changes in \bar{z} , data given by other workers were examined. The variations appeared to be closely associated with the persistence of a pressure gradient for winds from the south-westerly quadrant.

A large part of the residual variance is shown to be due to a marked regional variation, the association between monthly rainfalls being greatest in the south and least in the north. Maps of the residual z 's show that the association within groups of stations on the west coast or on the east coast was greater than that between the west and east coast groups.

XXVI. D. A. BOYD. "The Estimation of Rothamsted Temperature from the Temperature of Oxford and Greenwich." *Annals of Eugenics*, 1939, Vol. IX, pp. 341-353.

It is proposed shortly to analyse the effect of temperature on the Rothamsted crop-yields. For this purpose the mean temperature Q_0 for each crop year is required, and also quantities $Q_1 \dots Q_5$ proportional to the regression coefficients of a fifth degree polynomial fitted to the weekly mean temperature of each crop year. Rothamsted's temperature record did not commence until 1878, whereas yields for most of the classical experiments are available from 1852. The possibility of estimating the required values from the longer records of Oxford and Greenwich for the period 1852-3 to 1877-8 has therefore been investigated.

As a first step, the quantities Q were evaluated for a period of years (1878-9 to 1907-8) during which the three stations were concurrent, and the means, variances and covariances of each set of Q 's were calculated. Greenwich appears to have had a slightly more extreme climate than Oxford or Rothamsted, but this may have been due in part to the unorthodox exposure of the thermometers there. A significant increase in mean temperature over the period was noted, amounting to about 0.05°F . a year. Changes in the seasonal distribution of temperature were not significant. The variance of Rothamsted temperature was significantly smaller than that of Oxford or Greenwich, both from week to week, and from year to year. This noteworthy difference was doubtless due to the more upland situation of Rothamsted.

The linear regressions of the Q 's for Rothamsted on the corresponding values for Oxford and Greenwich were evaluated, taking the two stations individually and simultaneously. Oxford gave a better fit than Greenwich in every case, and the partial regression on the two stations was little better than the regression on Oxford alone. The fit was very good for the regression of Rothamsted on Oxford, the residual variance in no case exceeding 5 per cent.

Very satisfactory estimates of the mean annual temperature and of the regression coefficients up to the 5th degree may therefore be obtained for Rothamsted from the temperature records of Oxford only. At the same time differences of surprising magnitude have been revealed in the variability of weekly and annual temperature at Rothamsted as compared with Oxford and Greenwich.

(d) SAMPLING

XXVII. W. G. COCHRAN. "The Use of the Analysis of Variance in Enumeration by Sampling." *Journal of the American Statistical Association*, 1939, Vol. XXIV, pp. 492-510.

The results of a properly planned sampling investigation, in addition to providing an estimate of the accuracy of the method, often give estimates of

the accuracy of various alternative methods of sampling which might have been used. These estimates are helpful in increasing the efficiency of sampling in future studies on similar material. The use of the analysis of variance of the sampling results for this purpose is discussed and illustrated by a numerical example. The case in which an appreciable fraction, say, more than 10 per cent., of the total population is sampled is discussed briefly. The estimate of the relative accuracy of two methods of sampling is shown to be in most cases a simple function of the variance ratio, so that its sampling limits are easily obtainable. Some advice is given on the problem of analysing the results of large samples without excessive labour.

- XXVIII. W. G. COCHRAN. "The Information Supplied by the Sampling Results." (Appendix to a paper by W. R. S. Ladell). *Annals of Applied Biology*, 1938, Vol. XXV, pp. 383-389.

In any field experiment which involves sampling of a laborious nature, it is important to know as soon as possible what degree of accuracy in the treatment mean values will be reached with a given amount of work, how much work must be done to reach a given standard of accuracy and how best to distribute one's resources between the amount of sampling and the amount of replication.

The first sampling, whether it contains experimental treatments or is uniformly treated, can supply information on all these points if properly carried out. Ladell's first wireworm sampling is taken as a simple numerical example of the way in which these questions can be answered with the help of an analysis of variance.

The sampling and experimental errors of Ladell's experiments are discussed. The sampling error accounts for a large proportion of the experimental error in most cases, as it is always advisable where the labour involved in sampling is high.

Ladell's sampling errors agree well with those obtained under widely different conditions by Jones, and both may be recommended to other workers as an indication of the amount of variability to be expected in field sampling for wireworms.

- XXIX. W. G. COCHRAN. "Expected Errors in Diluting Bacterial Suspensions." (Appendix to a paper by H. L. A. Tarr). *Annals of Applied Biology*, 1938, Vol. XXV, pp. 633-643.

A knowledge of the amount of variation introduced by the process of dilution in the number of spores or vegetative cells in a solution is often of interest to bacteriological workers. The variations introduced by diluting consist of two parts (1) a sampling error, which with careful work will tend to follow a Poisson series distribution (2) the error involved in extracting rather more or less than the volume of liquid stated on the pipette. By making reasonable assumptions about the second source of error, standard errors and 5 per cent. limits of variation can be assigned to the number of spores or vegetative cells in the volume which is being used for experimental purposes. A table of these errors and limits is given, covering the range from 10^6 to 10^{10} spores per unit volume. Examples of its use are worked out.

THE SOIL

(Departments of Chemistry and Physics)

- XXX. G. NAGELSCHMIDT. "On the Atomic Arrangement and Variability of the Montmorillonite Group." *Mineralogical Magazine*, 1938, Vol. XXV, pp. 140-155.

A classification of clay minerals is based on their lattice structures and the quality of their X-ray powder diagrams. The montmorillonite group, with a three layer lattice and poor powder diagrams, is shown to have three end-members, which in the completely dehydrated state and free from isomorphous replacements are montmorillonite $Al_2Si_4O_{11}$, nontronite $Fe_2Si_4O_{11}$ and magnesium beidellite $Mg_3Si_4O_{11}$. Calculations of the isomorphous replacements for six of these materials showed that the excess cations balanced the negative charges resulting from the replacements. Further it was shown that for three of these materials all the excess cations were exchangeable, though there were discrepancies with magnesium beidellite.

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The hypothesis is advanced that a certain amount of isomorphous replacement of silicon by aluminium and perhaps of aluminium by magnesium is essential for this structural type. This may explain both the high water content, which is due to the excess cations, and the poor diffracting power for X-rays, which is due to the lack of regularity in the lattice.

X-ray powder data for the six samples and the values for the lattice shrinkage upon dehydration are given and discussed.

XXXI. E. W. RUSSELL. "*Soil Structure.*" Imperial Bureau of Soil Science, Technical Communication No. 37, 1938. Price 2s.

The problems concerned with the production and maintenance of a good soil structure, which is a fundamental element in good tilth, have been extensively investigated during the last few years. This review describes the many methods that have been devised for measuring the soil structure quantitatively, the degree of control that can be obtained over the soil structure by weathering, cultivation, the application of manures and the growing crops and the theories that have been put forward to explain the results.

XXXII. R. K. SCHOFIELD. "*Pore-Size Distribution as Revealed by the Dependence of Suction (pF) on Moisture Content.*" Transactions of the First Commission of the International Society of Soil Science, 1938, Vol. A, pp. 38-45.

By following the invasion of air into the pores of soil samples as the pF rises and its replacement by water as the pF falls a measure is obtained of the pore-size distribution.

When the suction does not exceed pF 6 (50 per cent. R.H.) there are good reasons for believing that results of the right order of magnitude are obtained by assuming the normal value for the surface tension.

Above pF 6 the direct adhesion of the water molecules to the solid surfaces and to the hydration of the exchangeable ions are probably the controlling factors.

XXXIII. B. A. KEEN. "*What Happens to the Rain ?*" Quarterly Journal of the Royal Meteorological Society, 1939, Vol. LXV, pp. 123-137.

An annual rainfall of 30 in. means that 3,000 tons of water fall on an acre of land. In the course of the year this all disappears, by run-off, evaporation, transpiration through vegetation, and by downward percolation. The relative importance of these factors in British and overseas conditions is discussed. Many of the traditional beliefs among farmers and gardeners were based on a theory of water movement that was attractively simple to understand—but incorrect. It is only in recent years that the true picture of the movement of water in the soil has been built up. In consequence, some of the traditional practices need revision, while others now have a different explanation. The new work has also clarified some of the concepts used in hydrology.

XXXIV. R. K. SCHOFIELD. "*The Representation of Soil Colour by Means of the C.I.E. Co-ordinates.*" Transactions of the First Commission of the International Society of Soil Science, 1938, Vol. A, pp. 54-59.

The way in which C.I.E. colour co-ordinates can be computed from the Maxwell spinning disk is explained.

A numerical example is worked out in detail by way of illustration, the hue wave-length, the purity and the relative brightness being also evaluated.

The cause of the differences in the matches obtained between soils and Munsell colour disks by different observers is explained, and it is concluded that such matches obtained by observers of unknown visual characteristics do not provide a satisfactory basis for soil colour nomenclature.

Various ways are discussed in which better results might be obtained.

MICROBIOLOGY

(Departments of Fermentation and General Microbiology)

- xxxv. E. H. RICHARDS. "Note on the Effect of Temperature on a Mixed Culture of Two Organisms in Symbiotic Relation." *Journal of Agricultural Science*, 1939, Vol. XXIX, pp. 302-305.

A study was made of nitrogen-fixation by *Azotobacter chroococcum* alone in a medium containing dextrose (which it can utilize) and in mixture with a coliform organism on a medium containing no carbohydrate except starch, which *Azotobacter* cannot utilize unless it be hydrolysed by the coliform organism or some other agency.

The amount of nitrogen fixed in the mixed cultures was found to be maximal at two temperatures, and a discussion is given of the causes thought to be operative in producing the double maximum.

- xxxvi. A. DIXON. "The Protozoa of some East Greenland Soils." *Journal of Animal Ecology*, 1939, Vol. VIII, pp. 162-167.

Soil samples from Kangerdlugssuak in East Greenland were examined. A large protozoan population was present even in those which were frozen for nine months of the year, the greatest number of species being found in the soils producing the richest vegetation. The testaceous Rhizopods in these soils were unusually numerous in some of the non-peaty samples.

THE PLANT IN DISEASE: CONTROL OF DISEASE

(Departments of Entomology, Insecticides and Fungicides,
and Plant Pathology)

(a) INSECTS AND THEIR CONTROL

- xxxvii. C. B. WILLIAMS. "The Migration of Butterflies in India." *Journal of the Bombay Natural History Society*, 1938, Vol. XL, pp. 439-457.

This account of the known migrations of butterflies of India was written at the request of the Bombay Natural History Society to stimulate interest in the subject in India. About eighty records relating to 52 species are discussed and tabulated. A map shows the localities where flights have been seen. The species migrating on the slopes of the Himalayas in North India are different from those migrating further south on the plains. The species migrating in South India are, however, very similar to those in Ceylon. There is some evidence of the flight seasons being related to the seasonal temperature changes in the north, and to the monsoon changes in the south.

- xxxviii. C. B. WILLIAMS. "Recent Progress in the Study of Some North American Migrant Butterflies." *Annals of the Entomological Society of America*, 1938, Vol. XXXI, pp. 211-239.

This is a summary and discussion of a number of new records of migration of butterflies in North America and particularly of the Monarch (*Danaus plexippus*), the Painted Lady (*Vanessa cardui*), and the Migratory Sulphur (*Phoebis eubule*). In the former southward autumn flights are found in the Eastern States down to Florida and in the Central Plains from the Great Lakes down to Texas. In the mountain areas there are no flights, but they are again found on the Pacific coast. In the Painted Lady invasions occur in the spring from the south apparently only from the arid portions of Western Mexico. Great immigrations occurred in 1924, 1926, 1931 and 1935 but none in the intervening years. For *Phoebis eubule* there is given a remarkable series of observations by Mr. P. Smyth lasting over eighteen consecutive years. Other species are also discussed.

- xxxix. K. J. FISHER (K. J. GRANT). "Migrations of the Silver-Y Moth (*Plusia gamma*) in Great Britain." *Journal of Animal Ecology*, 1938, Vol. VII, pp. 230-247.

An account of immigrations of the Silver-Y moth from 1932-1936. The flights in the last of these years was on a very extended scale and considerable

damage was done by the larvae. The moth was seen as far north as the Shetland Islands. The first immigrants were seen on May 6th, but the main immigration was in June. The data are analysed and show considerable evidence to support a return flight to the south in the autumn. The wind has no apparent influence on the direction of flight.

- XL. D. C. THOMAS. "Report on the Hemiptera-Heteroptera taken in the Light Trap at Rothamsted Experimental Station, During the Four Years 1933-1936." Proceedings of the Royal Entomological Society of London, A, 1938. Vol. XIII, pp. 19-24.

Seventy-four species of Heteroptera were identified of which 57 were of the family Capsidae. This latter number is about one-third of the known British species of Capsidae. Several species captured were new to the district. The Capsidae were predominantly males, and the Corixidae chiefly females.

- XLI. B. LOVIBOND. "The Fever Fly *Dilophus febrilis* L." Journal of the Board of Greenkeeping Research, 1938, Vol. V, pp. 271-273.

Fever fly grubs are frequently found in clusters on golf greens and are often confused with leather jackets. The damage consists of thin patches round the nests and loosening of the soil. The life history has been thoroughly investigated by other workers and is quite straightforward, there being two generations in the year. Lead arsenate has given good control.

- XLII. B. LOVIBOND. "*Meloe proscarabaeus* L." Journal of the Board of Greenkeeping Research, 1939, Vol. VI, pp. 42-45.

Specimens of the oil beetle *Meloe proscarabaeus* L. were troublesome on a Lancashire golf course but did not cause any actual damage to the turf. It was found that they mated and laid eggs readily under laboratory conditions. An excellent hatch was obtained but as the triungulins could not be persuaded to feed, it was impossible to carry them on to the adult stage.

- XLIII. K. N. TREHAN. "Two New Species of Aleurodidae Found on Ferns in Greenhouses in Britain." Proceedings of the Royal Entomological Society of London, B, 1938 Vol. VII, pp. 182-189.

Two new Whiteflies were found on ferns in the Fernhouse at the Royal Botanic Gardens at Kew. They are described as *Aleuroplatus kewensis* and *Trialeurodes williamsi*.

- XLIV. A. C. EVANS. "Studies on the Distribution of Nitrogen in Insects." I. In the Castes of the Wasp, *Vespula germanica* (Fab.)." Proceedings of the Royal Entomological Society of London, A, 1938, Vol. XIII, pp. 25-29.

In the adult wasp most of the nitrogen is present in the cuticle and soluble protein fractions, in prepupae little is found in the cuticle, but over 60 per cent. is in the form of soluble protein. Just emerged wasps probably contain a reserve protein, insoluble in water, which is utilised to complete the hardening of the cuticle. The fat-body of queens preparing for hibernation weighs about 25 per cent. of the body-weight and contains about 1.3 per cent. of nitrogen.

- XLV. A. C. EVANS. "Studies on the Distribution of Nitrogen in Insects. II. A Note on the Estimation and Some Properties of Insect Cuticle." Proceedings of the Royal Entomological Society of London, A, 1938, Vol. XIII, pp. 107-110.

The cuticle of *Tenebrio molitor* L. contains about 60 per cent. protein which is soluble in dilute acids and alkalis. The hypothesis is put forward that part of the material absorbed from the cuticle at the last larval moult may eventually be utilised to form the major part of the adult cuticle.

- XLVI. A. C. EVANS. "Physiological Relationships between Insects and their Host Plants. I. The Effect of the Chemical Composition of the Plant on Reproduction and Production of Winged Forms in *Brevicoryne brassicae* L. (Aphididae)." Annals of Applied Biology, 1938, Vol. XXV, pp. 558-572.

Under late summer conditions of light the rate of reproduction of the aphid *Brevicoryne brassicae* is positively correlated with the nitrogen content

of the host plant and, in particular, with the protein content. The formation of winged forms is negatively correlated with the same factors.

- XLVII. W. R. S. LADELL. "Field Experiments on the Control of Wireworms." with an Appendix by W. G. Cochran. *Annals of Applied Biology*, 1938, Vol. XXV, pp. 341-389.

An account is given of three field experiments planned to show the effect of soil insecticides on wireworms. One was in the form of a 5 x 5 latin square; the other two 3 x 10 and 6 x 8 randomised blocks. The mean density of wireworms before control was 65, 335 and 277 per square yard respectively. Distribution was uneven and thus introduced high sampling errors. Several fumigants showed significant reductions in the population, one of the best being crude naphthalene.

- XLVIII. F. TATTERSFIELD and J. T. MARTIN. "The Problem of the Evaluation of Rotenone-containing Plants. IV. The Toxicity to *Aphis rumicis* of Certain Products Isolated from *Derris* Root," with an Appendix by W. G. COCHRAN. *Annals of Applied Biology*, 1938, Vol. XXV, pp. 411-429.

An account is given of the preparation and a few of the properties of a compound isolated from the extracts of Sumatra-type *derris* root.

This compound yields optically inactive toxicarol in high yield, and is characterised by the switch-over from laevo- to dextro-rotation on the addition of caustic potash in methyl alcohol to its benzene solution, and is mainly responsible for this feature of the Sumatra-type resins under similar treatment. The change-over in rotation was followed by a gradual fall in rotation of a unimolecular type. The compound is laevo-rotatory in benzene and dextro-rotatory in alcohol.

The toxicities to *Aphis rumicis* of rotenone, toxicarol precursor, sumatrol, toxicarol and the residual resins from the Sumatra-type and *Derris elliptica* roots have been determined. In our experiments the toxicity in descending order was Rotenone > *D. elliptica* resin > Sumatra-type resin > sumatrol = toxicarol precursor > inactive toxicarol.

In the Appendix, the computations necessary to estimate the relative potencies of two insecticides from controlled experiments on insects are illustrated by a numerical example. A brief discussion is given of the appropriate tests of significance.

- XLIX. J. T. MARTIN. "The Chemical Evaluation of *Pyrethrum* Flowers (*Chrysanthemum cinerariaefolium*)." *Journal of Agricultural Science*, 1938, Vol. XXVIII, pp. 456-471.

Comparative analyses of *pyrethrum* flowers have been carried out by the methods of Tattersfield, Seil, Ripert, Haller and Acree and Wilcoxon.

The methods were of value in indicating the relative richness in pyrethrins of the samples tested, but discrepancies were seen in the absolute values of the pyrethrins I and II recorded. Under present conditions and until a standard method of analysis is agreed upon, it would appear requisite to state the method employed in the evaluation of the flowers.

The Wilcoxon method has given higher figures for the pyrethrin I content than the Seil method. The degree of divergence between the results depended upon the richness of the flowers, and upon the excess of acid used in distilling the volatile acid in the Seil method. The relationship between the amount of the pyrethrin I acid present and the titration recorded in the Wilcoxon method was not a linear one.

The question of the solvent to be used for the initial extraction of the flowers has been briefly discussed.

- L. S. H. HARPER. "A New Compound from *Derris elliptica* Resin." *Chemistry and Industry*, 1938, Vol. LVII, p. 1059.

By chromatographic absorption on alumina of a rotenone-free *D. elliptica* resin Buckley's compound is obtained. It has the formula $C_{20}H_{16}O_6$. A structure is assigned based on its similarity to *iso*-rotenone.

(b) FUNGUS DISEASES

- LI. S. D. GARRETT. "Soil Conditions and the Root-Infecting Fungi." *Biological Reviews*, 1938, Vol. XIII, pp. 159-185.

An examination is made of papers published during the last fifteen years on soil-borne fungus diseases of plants, with special reference to the influence of soil conditions on infection.

In reviewing the ecology of the root-infecting fungi, a distinction is drawn following Reinking, between *soil inhabitants* and *soil invaders*.

The *soil inhabitants* are considered to be primitive or unspecialised parasites with a wide host range; these fungi are distributed throughout the soil, and their parasitism appears to be incidental to their saprophytic existence as members of the general soil microflora.

The *soil invaders*, to which class the majority of the root-infecting fungi seem to belong, are more highly specialised parasites; the presence of such fungi in the soil is generally closely associated with that of their host plants. In the continued absence of host plant, such fungi die out in the soil, owing to their inability to compete with the soil saprophytes for an existence on non-living organic matter. This close association between the *soil invaders* and their host plants thus seems to be enforced by the competition of the general soil microflora.

The influence of soil conditions upon a number of soil-borne fungus diseases is tabulated and discussed under the headings of soil moisture content, texture, organic matter, reaction and chemical composition.

- LII. S. D. GARRETT. "Soil Conditions and the Take-all Disease of Wheat. III. Decomposition of the Resting Mycelium of *Ophiobolus graminis* in Infected Wheat Stubble Buried in the Soil." *Annals of Applied Biology*, 1938, Vol. XXV, pp. 742-766.

Decline in viability of the resting mycelium of *Ophiobolus graminis* in artificially infected wheat straw was followed under experimentally controlled soil conditions in glass tumblers. The results suggested that the disappearance of *Ophiobolus* from the straws was due to its natural decomposition by the other soil organisms, since, in its resting phase, the fungus tolerated adverse physical conditions of the soil better than those optimum for microbiological activity. The decline of *Ophiobolus* was hastened by the addition to the soil of energy materials poor or lacking in nitrogen, such as glucose, starch and rye-grass meal, whilst it was postponed by the addition of organic nitrogen in the form of dried blood, or of inorganic nitrogen, as ammonium carbonate. These results led to the hypothesis that the *Ophiobolus* mycelium is decomposed as a source of nitrogen by the micro-organisms engaged in breaking down the straw residues.

- LIII. S. D. GARRETT. "Soil Conditions and the Take-all Disease of Wheat IV. Factors Limiting Infection by Ascospores of *Ophiobolus graminis*." *Annals of Applied Biology*, 1939, Vol. XXVI, pp. 47-55.

No infection of wheat seedlings by the ascospores of *Ophiobolus graminis* could be obtained except under strictly pure culture conditions in bacteriologically sterile soil or sand. Yet such ascospores germinated well on nutrient agar, and the resulting mycelial cultures would produce infection of wheat seedlings growing under natural soil conditions. Failure of the ascospores to cause infection under ordinary soil conditions was attributed to competitive assimilation by the other soil micro-organisms of the root excretions, which in sterile soils are wholly available to the germinating ascospores.

(c) VIRUS DISEASES

- LIV. F. C. BAWDEN and N. W. PIRIE. "Liquid Crystalline Preparations of Potato Virus 'X'." *British Journal of Experimental Pathology*, 1938, Vol. XIX, pp. 66-82.

Methods are described for the isolation of nucleoproteins from *N. tabacum*, *N. glutinosa* and *Lycopersicum esculentum*, infected with the S and G strains of potato virus "X." These have not been isolated from healthy plants, and

the available evidence suggests that they are the viruses themselves. Infections were obtained with 10^{-9} gm., and specific serological reactions with $\frac{1}{6 \times 10^6}$ gm. Concentrated solutions are spontaneously bi-refringent and dilute solutions show anisotropy of flow; when sedimented by high-speed centrifugation the nucleoproteins form birefringent jellies, but when precipitated with acid or ammonium sulphate the material appears amorphous under the microscope.

The filterability of the virus after purification is less than that of the virus in untreated sap, and purification appears to cause the virus particles to aggregate into rods.

Two types of inactivation are described: one leads to a loss of infectivity without changing the optical properties or serological reactions, whereas the other denatures the protein and destroys all three. The effects of heating, drying, acid, alcohol, sodium dodecyl sulphate, irradiation with X-rays and ultra-violet light, and hydrogen peroxide are described. The properties of virus "X" are compared with those of tobacco mosaic virus, and the results discussed.

- LV. F. C. BAWDEN and N. W. PIRIE. "*Crystalline Preparations of Tomato Bushy Stunt Virus.*" British Journal of Experimental Pathology, 1938, Vol. XIX, pp. 251-263.

The isolation of a protein, probably the virus itself, is described from plants infected with tomato Bushy stunt virus. This protein not only differs from the normal plant proteins, but it also differs more from the other purified plant viruses than these differ from one another. It is fully crystalline instead of liquid crystalline. It has a higher nucleic acid content than tobacco mosaic virus or potato virus "X," and is more stable towards pH changes, but less stable towards dehydrating agents. Its particles are not elongated, and liquid and solid preparations are isotropic. 1 c.c. of solution containing 10^{-7} gm. produces infection when rubbed on to *N. glutinosa*, and 1 c.c. containing 10^{-6} gm. gives a specific precipitate with antiserum. Precipitates of the rod-shaped viruses with their antisera resemble those obtained with bacterial flagellar ("H") antigens, but those of Bushy stunt virus resemble those with somatic ("O") antigens. When irradiated with ultra-violet light or treated with nitrous acid the virus loses its infectivity, but it can still be crystallised and still retains its serological activity.

- LVI. F. C. BAWDEN and N. W. PIRIE. "*A Note on Some Protein Constituents of Normal Tobacco and Tomato Leaves.*" British Journal of Experimental Pathology, 1938, Vol. XIX, pp. 264-267.

Proteins with high molecular weights have been isolated from healthy tobacco and tomato plants. Except for their large size, these proteins have little in common with the plant viruses that have been purified. They contain 14-16 per cent. N., but less than 0.2 per cent. P and less than 1 per cent. carbohydrate, whereas the viruses are nucleoproteins.

- LVII. F. C. BAWDEN and F. M. L. SHEFFIELD. "*The Intracellular Inclusions of Some Plant Virus Diseases.*" Annals of Applied Biology, 1939, Vol. XXVI, pp. 102-115.

The contents of healthy cells and those infected with a number of different plant viruses are described. Some of these viruses apparently do not cause the production of intracellular inclusions; others cause the production of amorphous bodies only and the remainder produce both amorphous and crystalline inclusions. The properties of the inclusions are compared with those of purified preparations of the viruses. It is shown that insoluble complexes of the viruses with protamines, histones and proteins which in many ways resemble the intracellular inclusions can be produced *in vitro*. Possible explanations for the formation and disappearance of the inclusions in infected plants are suggested.

- LVIII. F. M. L. SHEFFIELD. "Vein Clearing and Vein Banding Induced by *Hyoscyamus III* Disease." *Annals of Applied Biology*, 1938, Vol. XXV, pp. 781-789.

The first symptom of Hy. III disease in tobacco is a clearing of the veins. This is followed later by vein banding. During clearing no anatomical or cytological abnormalities occur. The yellow colour is due to a retardation of chlorophyll formation.

When vein banding becomes apparent considerable hypertrophy is seen in the tissues near the veins and hypoplasia is apparent in the interveinal areas. Intracellular inclusions are abundant in all tissues except the xylem.

Cleared tissue contains 6-11 times as much virus per unit volume as does the banded tissue. The latter also contains less than do the yellower parts of banded leaves.

- LIX. M. A. WATSON. "Further Studies on the Relationship Between *Hyoscyamus Virus 3* and the *Aphis Myzus persicae*, with Special Reference to the Effects of Fasting." *Proceedings of the Royal Society of London, B*, 1938, Vol. CXXV, pp. 144-170.

The efficiency of *Myzus persicae* in transmitting Hy. 3 virus increases with increasing time of fasting before feeding on the infected plants. Their efficiency decreases with increasing feeding time on the infected plants up to one hour, at which time a constant low level is reached. Infectivity is lost by the aphides when fasting after infection feeding, but the loss is less rapid if the feeding time on the infected plants was very short. The rate of loss of infectivity appears to be more rapid than the rate at which the virus is inactivated *in vitro* in expressed plant sap. Individual aphides vary in their efficiency as vectors, but the relative efficiency of individuals can be altered if the preliminary fasting treatments are varied. The most probable explanation of these results is that the virus is inactivated by some substance secreted by the aphides when feeding.

- LX. F. M. L. SHEFFIELD. "Microsurgical Studies on Virus-Infected Plants." *Proceedings of the Royal Society of London, B*, 1939, Vol. CXXVI, pp. 529-538.

Cells of virus-infected plants were examined by micro-manipulative methods.

The pH of the cell contents was found to be the same in diseased and in healthy plants.

The non-crystalline intracellular inclusions of aucuba mosaic disease of tomato disintegrate immediately on slight mechanical pressure or on pricking. They are almost unaffected by acids from pH 7 to 2.2. They break down if the osmotic pressure is reduced below 0.07 M, but can be isolated into solutions of 0.1 M. These inclusions contain virus, but virus may also be dispersed through the cell.

The striate material of tobacco and enation mosaics cannot be isolated, as immediately it is touched with a micro-needle it breaks down into needle-like fibres.

APICULTURAL PROBLEMS (Section for Bee Investigations)

- LXI. H. L. A. TARR. "Studies on American Foul Brood of Bees." II. *The Germination of the Endospores of Bacillus larvae in Media containing Embryonic Tissues*," with an Appendix by W. G. COCHRAN. *Annals of Applied Biology*, 1938, Vol. XXV, pp. 633-643.

The difficulty of producing vegetative growth from the spores of *Bacillus larvae*, the organism responsible for American foul brood of bees, even on rich media such as a complex egg yolk carrot extract suggested the possibility of using media containing the tissues of the developing chick embryo. Experiments comparing four different media showed that chick embryo "brei" and the chorioallantoic membrane of the developing chick are by far the most favourable media yet found for the growth of this organism. Added available nitrogen in the form of beef digest broth to the embryo brei tended to inhibit

germination. Concentrations of reducing sugars up to 12.5 per cent. caused no apparent reduction in the germination of *B. larvae* spores on the chick embryo media. This is of interest because of previous suggestions that the reducing sugar content of bee larvae at various stages in their development might be connected with the age-incidence of American foul brood.

- LXII. H. L. A. TARR. "Studies on American Foul Brood of Bees. III. The Resistance of Individual Larvae to Inoculation with the Endospores of *Bacillus larvae*." *Annals of Applied Biology*, 1938, Vol. XXV, pp. 807-814.

Experiments are described in which attempts were made to produce American foul brood by the direct inoculation of eggs, or of larvae from the time of hatching up to that just subsequent to sealing, by placing aqueous suspensions of the washed spores of *Bacillus larvae* in the cells. In no case did the disease develop in the colony into which the inoculated larvae were introduced. Positive results were, however, obtained by spraying a comb containing eggs and young larvae with an aqueous suspension of the spores of *B. larvae*, the disease becoming evident seven days after spraying. Since in this case the adult bees had access to the spore suspension it can be inferred that the adult bee plays an important part in the inoculation of the brood. Experiments designed to test the possibility that *B. larvae* undergoes some change during its carriage by the adult bee yielded negative results.

- LXIII. H. L. A. TARR. "Studies on European Foul Brood of Bees. IV. On the Attempted Cultivation of *Bacillus pluton*, the Susceptibility of Individual Larvae to Inoculation with this Organism and its Localisation within its Host." *Annals of Applied Biology*, 1938, Vol. XXV, pp. 815-821.

Attempts to grow *Bacillus pluton*, the causal organism of European foul brood in bees, on the minced tissues of the chick embryo, or on its chorio-allantoic membrane were unsuccessful, in contrast to *B. larvae*, which grows well on these media. Small doses of *B. pluton* which were unable to produce growth on chick embryo medium or on beef digest brood filtrate medium were instrumental in causing European foul brood in young bee larvae when placed in the cells along with the normal brood food. Stained sections cut from larvae of all ages and showing all stages of the disease showed that *B. pluton* is localised in the food mass within the peritrophic membrane. The disease is shown to be a purely intestinal infection of the bee larva. The organism responsible is a strict parasite.

TECHNICAL AND OTHER PAPERS

GENERAL

- LXIV. E. J. RUSSELL. "Science and the Indian Peasant." *Journal of the Royal Society of Arts*, 1939, Vol. LXXXVII, pp. 662-674.
- LXV. E. J. RUSSELL. "National Planning in Agriculture: its Possibilities and its Limits." *Nineteenth Century and After*, 1938, Vol. CXXIV, pp. 187-199.
- LXVI. E. J. RUSSELL. "Poland To-day." *Journal of the Royal Society of Arts*, 1938, Vol. LXXXVII, pp. 125-128.
- LXVII. B. A. KEEN. "What Happens to Rain." *The Listener*, 1939, Vol. XXI, pp. 319-320.
- LXVIII. J. MEIKLEJOHN. "The Starling—Friend or Enemy?" *Journal of the Royal Agricultural Society of England*, 1938, Vol. XCIX, pp. 37-53.

This paper contains a review of the present knowledge of the status and habits of the starling, especially those which are of agricultural importance. It also contains an estimate of the density of the starling population in several parts of England, taken from comparative counts of nests, and an account of an experiment on the recovery of plants bitten off by birds.