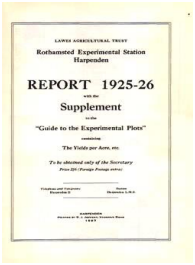
Report 1925-26 With the Supplement to the Guide to the Experimental Plots



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Rothamsted Research

Rothamsted Research (1926) *Summaries of Papers Published, 1924, 1925 - I. Scientific Papers ;* Report 1925-26 With The Supplement To The Guide To The Experimental Plots, pp 54 - 84 **- DOI: https://doi.org/10.23637/ERADOC-1-84**

SCIENTIFIC PAPERS

Published 1925 and 1926, and in the Press.

I.—CROPS, PLANT GROWTH AND FERTILISER INVESTIGATIONS.

(Botanical, Chemical, Insecticides and Fungicides Departments, and Field Experiments Section.)

I. K. WARINGTON. *"A Botanical Study of the Flax Plant. Manurial Pot Experiments with Flax."* The Linen Industry Research Association, Research Institute Memoirs, Vol. III., pp. 29-36.

As varied opinions are held on the best manuring for flax, water culture and pot experiments (with soil and sand) were carried out to test the matter further, particularly with regard to the importance of potassium and phosphorus. When a heavy and poor Rothamsted soil was employed, an addition of potassium or nitrogen caused but little improvement in the crop, whereas a dressing of phosphate was of considerable benefit. Thus, although potassic fertilisers are usually regarded as especially beneficial for flax, in the case of this soil phosphate plays the more important part. Early start and early maturation in particular appear to depend on the supply of phosphate. On the other hand, nitrogenous dressings definitely retard ripening, and are unsuitable as fertilisers for flax, unless, of course, there is an actual nitrogen deficiency in the soil.

In sand and water culture, as would be expected, the use of both potassium and phosphate, as well as the other nutrient salts, was found to be necessary. The greater importance of phosphate was also evident in these cases, especially in sand cultures, since additional supplies of potassium proved useless in the absence of an adequate amount of phosphate; and further, luxuriant growth was possible for some time where no potassium had been given, provided that a large quantity of phosphate was present.

The results from these three types of experiment thus afford corroborative evidence as to the importance of a liberal supply of phosphate, and at the same time show the possibility of danger arising from lack of potassium or excess of nitrogen.

II. W. E. BRENCHLEY, E. J. MASKELL, and K. WARINGTON. *"The Inter-relation between Silicon and other Elements in Plant Nutrition."* Annals of Applied Biology, 1927, Vol. XIV., pp. 45-82.

The role of silicon in plant nutrition has attracted much attention owing to the large amount that is found in cereal plants, but the true function of the element is still debatable. Widespread belief exists that silicon is capable of replacing phosphorus or other essential elements to some extent, and experiments were undertaken to endeavour to throw light on this point.

Under controlled conditions in water cultures, soluble silicate was found to have little effect upon the growth of barley if phosphorus were also present, but if the latter were absent, a significant increase in dry weight was induced by the silicate. The addition of silicate caused an appreciable increase in the height

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of the main shoot, which was most marked in phosphate-free solutions, becoming less evident as the quantity of phosphate present was increased. Leaf development was retarded by phosphate deficiency, and hastened by the addition of silicate. A close association exists between the amount of phosphate present and the effect of silicate upon the rate of tillering and the number of tillers developed.

The possibility of obtaining soluble silicates in considerable quantity from certain manufacturing processes led to an enquiry as to whether such silicates could advantageously be used to supplement or even replace certain of the artificial fertilisers in common use. Soluble silicates tend to cause increase in dry weight with deficient mineral manuring, and in some cases also with complete manuring, and they are more active in this respect than are glass silicates. Further soil experiments revealed variations in the response of barley and mustard to silicate on different types of soil. A general improvement occurred with increasing doses of silicate together with various combinations of manures, notably when phosphorus or potash was deficient.

The significance of the results obtained has been examined statistically, and an attempt made to formulate the effect of added silicate in terms of an increase in the efficiency of the superphosphate present.

III. W. E. Brenchley and K. Warington. *"The Rôle of Boron in the Growth of Plants."* Annals of Botany, 1927, Vol. XLI., pp. 1-21.

The important rôle of boron in the nutrition of *Vicia faba* was clearly shown in Warington's earlier work, but it remained to be proved whether the beneficial action of the element is a general phenomenon or is confined to particular conditions of growth. Further experiments suggest that the need of certain plants for boron is unaffected by the nature of the substratum on which they grow, the conditions of aeration at the roots or, in the case of leguminous plants, the presence or absence of nodules thereon. Plants grown in water cultures need the element irrespective of the composition or pH value of the nutritive solution. The concentration of boric acid appears to be of little moment provided that an adequate, though not excessive, total supply is provided over a given period, but this total supply can be reduced when the nutritive solution is frequently renewed. The need for boron still manifests itself even when the nutrient solution is kept at approximately constant concentration by means of drip cultures.

Boron *per se* is shown to be the active principle in these phenomena, for the chemical combination in which boron is presented to the plant is immaterial, even the so-called "insoluble" borates being effective; but no other element, out of fifty-two tested, has proved capable of replacing boron. Special attention has been given to manganese in this connection. It has been claimed by other workers that boron is probably essential to the growth of all plants, but so far in these experiments this has only been proved for several leguminous plants and for melon, whereas various cereals and candytuft complete their development in its absence. It is not yet certain whether the distinction between these two classes is real or merely a matter of degree, i.e., whether

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the second class require so little boron that a sufficient supply is stored up in their seeds. The physiological function of boron in the nutrition of broad bean is under investigation. Boron is not able to replace any one of the essential nutritive elements, but a definite association with the absorption or utilisation of calcium is very strongly marked. The boron does not act as an ordinary catalyst, but is itself absorbed, and in some way removed from action, a constant supply thus being necessary.

IV. K. WARINGTON. *"The Changes Induced in the Anatomical Structure of Vicia faba by the Absence of Boron from the Nutrient Solution."* Annals of Botany, 1926, Vol. XL., pp. 27-42.

Broad beans grown in a medium entirely free from boron exhibit characteristic symptoms in the shoot and root. The stem withers and blackens at the apex, the injury gradually travelling down the plant, while the root system became stunted, the laterals being few in number and often thickened. The anatomical structure of such plants is shown to be abnormal, whereas the anatomy of plants supplied with a nutrient solution containing a small quantity of boron, e.g., boric acid 1 : 2,500,000, is similar to that of plants grown in soil.

The principal changes induced by the omission of boron are :

(*a*) Hypertrophy of the cells of the cambium followed by degeneration with discoloration, or direct disintegration of the same tissue without previous enlargement.

(*b*) Frequent disintegration of phloem and ground tissue.

(*c*) Poor development of xylem and in some cases ultimate breaking down of this tissue.

A definite connexion exists between the presence or absence of boron and the anatomical structure, and the correlation of this with the meristematic activity of the plant is discussed.

V. E. J. MASKELL. *"Field Observations on Starch Production in the Leaves of the Potato."* Annals of Botany, 1927, Vol. XLI., pp. 327-344.

This paper gives a preliminary survey of the physiological processes of starch production in the leaves of potato plants (variety Kerr's Pink) subjected to various manurial treatments. The four treatments were (1) No Potash; (2) Potash as Sulphate of Potash; (3) Equivalent Quantity of Chloride of Potash; (4) Potash Manure Salts equivalent to other treatments in K_2O content. This manure contains a higher concentration of chloride than (3). Full details of treatments are given on page 138.

The method used to estimate the starch consisted of comparing the colour tones developed by the Sachs iodine test with the appropriate colour standard in Ridgeway's "Colour Standards and Nomenclature," (No. 59 ''''). Laboratory experiments with starch impregnated filter paper showed that an increment in tone number corresponded with a proportional increment in starch concentration.

The experimental procedure consisted of covering a pair of

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leaflets with small light proof paper bags, leaving them to translocate over-night. Next day, one of the bags on each of six pairs was removed for 3 hours, and after the leaf had been exposed for 3 hours, that leaf and its covered pair were removed. This gave a measure of net assimilation. On eleven occasions between September 4th and 21st, samples were taken.

The data were analysed by Fisher's variance method, and the difference between two means which was statistically significant determined to be 0.588.

The following table shows the superiority of the K_2So_4 treated samples :—

K_2So_4—KCl : 0.528.
K_2So_4—P.M.S. : 0.774.
K_2So_4—NoK : 0.654.

The chloride treatments give a starch production not significantly greater than the no potash plot. The low rate of starch production in the less favourable treatments is shown to be associated with, though not casually related to, a low rate of starch removal. The analysis of variance shows that those portions due to occasion are significant. Some of this is ascribable to age and some to radiation.

A series of correlations between (1) Starch production, (2) Radiation, (3) Age, was determined with the following results :—

$r_{1.2}$ is hardly significant, but $r_{2.3}$ and $r_{1.3}$ are definitely so. The partial correlations $r_{12.3}$ and $r_{13.2}$ for each treatment separately show that the only significant correlation of starch production with radiation is on the no potash plot, and that this plot has the lowest correlation of starch production with age.

VI. W. A. Roach. *"A Laboratory Apparatus for the Wet Grinding of Plant Tissues out of Contact with Air."* Biochemical Journal, 1925, Vol. XIX., pp. 783-786.

A simple laboratory apparatus was designed by means of which potato tubers or similar tissues could be pulped sufficiently finely to ensure almost every cell being broken. The whole operation may be done in an atmosphere of an inert gas.

VII. W. A. Roach. *"On a Labile Blue Compound from the Potato Tuber."* Annals of Botany, 1925, Vol. XXXIX., p. 883.

Juice obtained by pulping potatoes and filtering the juice, both operations being carried out with careful exclusion of all oxygen (Paper No. VI.), was of a bluish green colour. When air was admitted very cautiously, the colour became bluer and darker, then changed through shades of green to a bright yellow ; the blue colour was discharged by sodium hydrosulphite, but came again on introducing more oxygen. The yellow colour was unaffected by the sodium hydrosulphite. In these respects the blue compound resembled the one obtained by Haas and Hill (Biochem. J. 1925, XIX. 236) from *Mercurialis perennis*.

VIII. E. M. Crowther. *"A Note on the Availability of Organic Nitrogen Compounds in Pot Experiments."* Journal of Agricultural Science, 1925, Vol. XV., pp. 300-302.

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A comparison was made of the manurial action of sixteen typical nitrogen compounds in pot experiments on barley, followed by mustard. An index of the availability of the nitrogen was afforded by the values for the total amount of nitrogen recovered in both crops (excluding the roots) in excess of that of the untreated series, expressed as a percentage of the added amount (0.5gm. per 10 kilos of soil). In order of decreasing availabilities the compounds gave the following percentage recoveries of nitrogen: 60-70 per cent., animoacetic acid; 50-60 per cent., sodium nitrate; 40-50 per cent., oxamide, ammonium sulphate, dried blood, acetamide; 30-40 per cent., egg albumen (nitrobenzene), peptone, pryidine, sodium urate; 20-30 per cent., sodium cyanide; 10-20 per cent., *d*-Napthylamine (aniline); less than 10 per cent. (acetanilide), hydrazine. The three substances enclosed in brackets gave irregular results; nitrobenzene prevented the germination of barley, aniline and acetanilide seriously reduced the germination and final yield of barley; nitrobenzene and aniline gave abnormally heavy growths of mustard.

IX. E. M. Crowther. "*Further Experiments on the Effect of Removing the Soluble Humus from a Soil on its Productiveness.*" Journal of Agricultural Science, 1925, Vol. XV., pp. 303-306.

In 1915, Weir published an account (Journ. Agric. Sci. (1915), VII, 246-253) of pot experiments from which it appeared that the removal of a considerable proportion of the soluble humus by acid treatment and repeated extraction with alkali had no effect in diminishing the productiveness of the soil. Six further crops have been grown in the pots set up by Weir, and an analysis of the whole of the data from two independent series of experiments (with 10 and 7 crops respectively) in each of the two soils shows that his conclusion must be modified. The results of several catch-crops of mustard and rye, grown out of season, are excluded, as they failed to make appreciable growth. The remaining crops (5 in the first and 4 in the second series) made a satisfactory growth. In both series the extraction of a heavy loam from Harpenden Field increased the yield in the first and second crops, but decreased it in the succeeding crops. The extraction of a garden soil from the Allotment decreased the yield in all cases, except for a slight and scarcely significant increase in the first crop in one series only. There is thus no evidence for the view that the soluble humus is unimportant as a source or reserve of plant food.

X. E. J. Russell. "*The Institute of Brewing Research Scheme: Third Report on the Experiments on the Influence of Soil, Season and Manuring on the Quality and Growth of Barley,* 1924." Journal of the Institute of Brewing, 1925, Vol. XXXI. (Vol. XXII., New Series), pp. 548-561.

This paper gives a full account of the work discussed on p. 20.

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XI. H. Lloyd Hind, H. Threadgold and C. W. B. Arnold. *"The Determination of the Diastatic Power of Malt and Barley."* Journal of the Institute of Brewing, 1926, Vol. XXXII., pp. 26-32.

An improvement in the standard method of determination of diastatic power, by working at a constant hydrogen ion concentration corresponding to pH 4.6, obtained by the addition of an acetate buffer.

XII. R. G. Warren, C. T. Gimingham and H. J. Page. *"The Chemistry of Basic Slag I. The Determination of Fluorine in Basic Slag."* Journal of Agricultural Science, 1925, Vol. XV., pp. 516-528.

A method is described for the determination of fluorine in basic slag. The fluorine content and the citric solubility of a number of basic slags are compared. On the assumption that fluorine in basic slag locks up in an unavailable condition an equivalent amount of phosphate, in the form of fluorapatite $[Ca_3 (PO_4)_2]_3 CaF_2$, an "availability value" is calculated from the fluorine content. In general, the values so obtained run parallel with the citric solubilities, but certain discrepancies occur, which will form the subject of further work.

II. STATISTICAL METHODS & RESULTS.

(Statistical Department.)

XIII. R. A. Fisher. *"Theory of Statistical Estimation."* Proceedings of the Cambridge Philosophical Society, 1925, Vol. XXII., pp. 700-725.

An ordered exposition of the recent developments of the theory of statistical estimation, and of the criteria which now exist for judging the value of statistical methods. The properties, first of consistent, and then of efficient statistics, are deduced, and a general method is given of obtaining an efficient statistic without the solution of transcendental equations. A property of efficient statistics is utilised to supply a measure of the intrinsic accuracy of error distributions, and this in turn to extend the notion of efficiency to statistics derived from small samples. The peculiar character of statistical estimates classed as sufficient is elucidated; and, in the absence of these, a method is given of evaluating the loss of information involved in the maximum likelihood solution, and of other efficient statistics. Finally, it is shown how ancillary statistics may be used to remove this residual loss of information.

XIV. P. R. Ansell and R. A. Fisher. *"Note on the Numerical Evaluation of a Bessel Function Derivative."* Proceedings of the London Mathematical Society, June 1925.

In the evaluation of a numerical expression involving the derivative of a Bessel function with respect to its modulus, it was found to be expressible in terms of the cosine-integral tabulated by

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Glaisher. This suggested the possibility that a general relationship, hitherto unsuspected, might subsist between the two functions. On examination, such was found to be the case, and in the present note the derivative, for values of the modulus equal to the halves of odd integers, is expressed in terms of the sine— and cosine—integrals.

XV. R. A. FISHER. *"The Resemblance between Twins, a Statistical Examination of Lauterbach's Measurements."* Genetics, 1925, Vol. X., pp. 569-579.

Previous data on the resemblance between human twins, though somewhat scanty, have shown themselves upon examination in surprising disaccord with the current biological theory of their origin. In this paper the extensive series of measurements obtained by Lauterbach has been examined, and is found on each point to be in substantial agreement with biological theory. There is every indication, within the group of like-sex twins, of a considerable class of genetically identical pairs, the correlation between whose measurements is found to be about .92; moreover, in the absence of errors of measurement, an even higher degree of resemblance is indicated.

XVI. R. A. FISHER. *"Sur la Solution de l'equation Integrale de M. V. Romanovsky."* Comptes Rendus de l'Academie des Sciences, 1925, Vol. CLXXXI., pp. 88-89.

The Russian mathematician Romanovsky had expressed the distributions obtained by sampling the normal frequency surface in the form of an integral equation. The present note gives the solution of the equation and demonstrates its agreement with the distributions previously obtained by the author, from considerations of the geometry of Euclidean hyper-space.

XVII. L. H. C. TIPPETT. *"On the Effect of Sunshine on Wheat Yield at Rothamsted."* Journal of Agricultural Science, 1926, Vol. XVI., pp. 159-165.

The object of this enquiry was to ascertain to what extent, if any, the apparent deleterious effect of rainfall upon the yield of wheat at Rothamsted should be ascribed to associated lack of sunshine, and in so far as the records would allow to evaluate the independent effect of the latter. The method employed was to utilise the effects of rainfall previously obtained for the whole 70-year period, and from the 34 years' sunshine records to obtain (i) the regression and residuals of sunshine upon rainfall, and (ii) the regression of crop residuals upon sunshine residuals.

The correlation of rain and sunshine is only about 0.23, and the effect ascribable to rain is in all essential features unchanged; a small proportion of the harmful effect of rainy weather from April to August should, however, be ascribed to associated lack of sunshine. The predominant effect of sunshine appears, however, to be in the end of autumn (October-December), suggesting that bright weather is important at this season in germinating the seed and establishing the seedling plants.

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XVIII. W. A. MACKENZIE. *"Note on a Remarkable Correlation between Grain and Straw, obtained at Rothamsted."* Journal of Agricultural Science, 1926, Vol. XVI., pp. 275-279.

A considerable amount of unpublished material has in the past been accumulated at Rothamsted upon the important subject of the correlation between grain and straw from cereal crops; when the yields from a recent uniformity trial with wheat (Sawyers Field) were examined, it was therefore at once observed that the grain and straw were there correlated in quite an exceptional degree. The correlation was found to be no less than 0.990, and in the present paper the significance of such a result is examined in relation (i) to the uniformity of the field, and (ii) to the accuracy of the newly-established methods of plot technique.

XIX. R. A. FISHER. *"Baye's Theorem and the Fourfold Table."* The Eugenics Review, 1926, Vol. XVIII., pp. 32-33.

Considerable statistical controversy has been aroused on the question of the distribution of a certain quantity X^2, necessary to test the independence, when calculated from a fourfold table. Prof. Pearson's original theory that its mean value is 3, having been disputed upon different grounds by Yule and Fisher, who agree that the mean value must be unity. In the present note, the large number of 11,668 fourfold tables, put on record in a recent paper by Mr. E. S. Pearson, is utilised to test the point. The 17 averages obtained range from 0.8926 to 1.0882, the general average being almost exactly unity.

XX. R. A. FISHER. *"On the Random Sequence."* Quarterly Journal of the Royal Meteorological Society, 1926, Vol. LII., p. 250.

The "runs" of increasing or decreasing sequences which occur in a series of numbers arranged in random order are of some interest to meteorologists. This note gives the mathematical distributions of the frequency of length of run.

XXI. R. A. FISHER. *"Applications of 'Student's' Distribution."* Metron, 1926, Vol. V., pp. 90-104.

XXI. (a) R. A. FISHER. *"Expansion of 'Student's' Integral in Powers of n^{-1}."* Metron, 1926, Vol. V., pp. 109-112.

The increasing use, both in agriculture and in general statistics, of the error distributions discovered by "Student" in 1908, has created a need for improved tables. The opportunity of their preparation by that writer was taken of publishing simultaneously a comprehensive account of the numerous applications to which his methods have since been shown to be adequate. The first of these papers explains and illustrates the several groups of problems, of which an exact solution is provided by the tables; the second gives the expansion formula by which values outside the range of the tables may be calculated, and in parts of the region tabulated increased accuracy attained.

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III. THE SOIL.

(Chemical, Physical and Statistical Departments.)

(a) Mechanical Analysis.

XXII. A Sub-Committee of the Agricultural Education Association. *"The Mechanical Analysis of Soils: A Report on the Present Position, and Recommendations for a New Official Method."* Journal of Agricultural Science, 1926, Vol. XVI., pp. 123-144.

This paper condenses the results of over two years' investigations at a number of centres, including Rothamsted. The work of the Sub-Committee was co-ordinated from Rothamsted by Dr. Keen. A thorough examination has been made of the function and significance of mechanical analysis in the light of recent advances in our knowledge of soil, and a comprehensive trial has been made of (a) a new method of dispersion, and (b) an improved single sedimentation method of analysis. These new procedures have been compared in detail with the original beaker method adopted by the Association in 1906, and, on the recommendation of the Committee, have been officially adopted in place of the older method.

Treatment of the soil with 20 vol. hydrogen peroxide prior to addition of hydrochloric acid is shown to effect a much better dispersion of the compound particles than that obtained with acid alone. The efficiency is due to the action of the peroxide on the cementing organic matter, some 80 per cent. of which is removed as gas or rendered soluble. There is at the same time a small chemical action largely confined to the finest mineral particles, a loss of 1 per cent. to 2 per cent. being usually found.

The dispersed material was submitted to mechanical analysis both by the old beaker method and the new method, which depends on taking samples with a pipette from the sedimenting column of material at specified depths and times.

The complete set of tests involved four series representing the combination of the two methods of dispersion with the two methods of analysis, and the full set was done on each of eight carefully chosen typical soils.

A complete set of experiments was carried out at Rothamsted, Leeds and Bangor, so that comparisons were available of the same methods in the hands of several different workers. Thus very adequate data were obtained on which to base the recommendation of the new method, full details of which are given in paper No. C.

XXIII. J. R. H. Coutts and E. M. Crowther. *"A Source of Error in the Mechanical Analysis of Sediments by Continuous Weighing."* Transactions of the Faraday Society, 1925, Vol. XXI., pp. 374-380.

In the determination of the size distribution curves of suspensions by the method of continuous weighing of the sediment accumulated on a balance pan hung near the base of a column of suspension, all previous workers have tacitly assumed that the course of the sedimentation is unaffected by the presence of the pan. This assumption has been examined experimentally and found to be incorrect. The pan shields the liquid below it from

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the entry of particles from higher levels, whereas the liquid in the annular region between the pan and the walls of the vessel experiences no such effect. Hence, the lower density of suspension immediately below the pan after the sedimentation has proceeded for a few minutes, inevitably sets up a flow of liquid which interferes with the free vertical fall of the particles. With the large, narrow-rimmed pans hitherto used, the observed yields are appreciably below the theoretical values. In extreme cases, with about 1cm. between the pan and the base of the cylinder, the observed yields may be as low as 70 per cent. of the theoretical yields. With the pan close to the base, the error is smaller, but there is a rapid change of yield with very small changes in the position of the pan. The extent of the disturbance varies with the size of the particle, and thus produces a distortion of the distribution curve.

(*b*) PHYSICAL PROPERTIES.

XXIV. B. A. KEEN. *"The Physicist in Agriculture, with special reference to Soil Problems."* Lecture to the Institute of Physics, November, 1925. From "Physics in Industry," Vol. IV. (1926).

A connected account of the properties of soil from the viewpoint of the physicist, and based very largely on the work of the Soil Physics Department at Rothamsted. Among the subjects dealt with are particle size and its measurement, the soil colloids, the mechanism of water movement in soil, soil tilth and soil cultivation.

XXV. B. A. KEEN, E. M. CROWTHER and J. R. H. COUTTS. *"The evaporation of Water from Soil. III. A Critical Study of the Technique."* Journal of Agricultural Science, 1926, Vol. XVI, pp. 105-122.

Experiments on the evaporation of water from a soil paste spread in shallow pans, showed that the drying proceeded very irregularly over the soil mass. Considerable portions became almost completely dry, whilst other portions remained very wet. There was a rough relationship between the form of the dry patch and the shape of the corresponding evaporation rate curves.

An improvement in technique was effected by exposing the soil in thin layers below glass plates. Under these conditions, reproducible results were obtained. Soil and kaolin, but not sand, gave considerable linear portions over the region of decreasing rate of evaporation. Tests on soil exposed as central discs, or peripheral rings, and on partially covered full plates, showed that, owing to the type of air currents set up, the drying was largely confined to the outer edges during the early stages.

The establishment of a moisture gradient in this way was subsequently opposed by the lateral movement of water by capillarity.

By interposing a barrier to the lateral spread of the air currents, the rate of evaporation was reduced to one-quarter and the resulting curves approximated to the liming case of slow evaporation, *i.e.*, vapour pressure curves.

The evaporation of water is controlled by two groups of

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factors depending on (1) the soil-water relationships, and (2) the environmental conditions. The latter group includes such factors as diffusion of water vapour from the soil to the acid, and bulk air movements set up by (*a*) the temperature gradient from bottom to top of the evaporating chamber, (*b*) the cooling of the soil by evaporation, (*c*) inevitable disturbance in the weighings, (*d*) the lower density of moist air. Thus the environmental conditions are very complex and liable to irregular changes from one experiment to another. Differences in the rate curves for various materials cannot, therefore, be attributed solely to the water relationships of the material. Where the results are obtained by a carefully controlled and reproducible technique, certain comparisons can be made, but caution must be exercised at present in associating precise physical explanations with the shape of the complete rate curves.

XXVI. W. B. HAINES. *" Studies in the Physical Properties of Soils. II. A Note on the Cohesion Developed by Capillary Forces in an Ideal Soil."* Journal of Agricultural Science, 1925, Vol. XV., pp. 529-535.

In this note an approximate calculation is made of the forces due to surface tension of water-films distributed through an " ideal " soil consisting of an assemblage of uniform spheres in regular packing. An expression is obtained for the value of the cohesion or shrinkage pressure produced, which shows that, although the cohesion rises toward zero moisture, it approaches a finite limit. If moistures are expressed in percentage by weight (as is usual in soil work), then the calculation is only valid below moisture values of 3—8 per cent., according to closeness of packing. For higher moistures a general inference is made that the cohesion again rises, which is supported by a very rough single value calculated for saturation.

The main conclusion reached is that the magnitude of these capillary forces depends almost wholly on the size of the particles. For any one particle size the range of cohesion for all moisture values is not large. On the other hand, the cohesion may be made to assume large values by making the particle size sufficiently small.

An attempted experimental verification is described in which a sample of ignited silt was taken as an approximation to the ideal soil and measurements of cohesion made with Atterberg's apparatus. This instrument measures the force required for the penetration of a wedge into the sample under test. The results agree well enough with the theoretical value at saturation, but not with the values at lower moistures. (*See* also papers XXVIII. and XXIX.)

XXVII. W. B. HAINES. *" Studies in the Physical Properties of Soils. III. Observations on the Electrical Conductivity of Soils."* Journal of Agricultural Science, 1925, Vol. XV., pp. 536-543.

The change of electrical conductivity with variations in moisture content has often been advocated as a convenient method for making soil-moisture measurements. This paper describes some tests made under laboratory conditions to investigate the

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validity of such a method. The technical difficulties concerned with unspecified variations in soil packing, or the nature of the electrode contact were eliminated in order to trace the exact changes in conductivity with changing moisture. The curves showing these changes for several different soil types, indicate that in most cases and above the hygroscopic point, the electrical conductivity could be used as a measure of the moisture. As the curves vary a good deal in shape from one soil to another, a preliminary examination of the soil would be necessary.

On the other hand, in the four cases of heavy clays examined, the conductivity was constant over a great part of the higher moisture range, so that exact inferences of moisture content could not be made from the conductivity measurements. It was also noticed in these cases that a close relationship exists between the critical point where the electrical conductivity begins to fall and a similar critical point in the shrinkage behaviour of the clay, thus providing an interesting connection between the electrical and mechanical behaviour of clay.

Measurements made on an ignited soil led to an interesting verification of earlier work on the capillary behaviour of water in soils, and in particular of the moisture contents at which the film continuity ceases. The shape of the conductivity curve for ignited soil gave clear proof of the values arrived at earlier. Results of previous workers using sand are shown to bear out the same conclusion.

XXVIII. R. A. Fisher. *"On the Capillary Forces in an Ideal Soil; Correction of Formulæ given by W. B. Haines."* Journal of Agricultural Science, 1926, Vol. XVI., pp. 492-505.

The statical treatment of the capillary action between adjacent soil particles is reworked, and certain corrections introduced into Haines' formulæ (Paper No. XXVI.). It is suggested that the discrepancy between theoretical stress and the experimental values reported may be removed by the supposition that the measurements were better designed to measure the work needed to cause rupture than the static stress of the system. Finally, the limitations of the geometrical approximation adopted are removed by recalculating the volumes, pressures and stresses from the true capillary surface.

XXIX. W. B. Haines. *"Studies in the Physical Properties of Soils. IV. A Further Contribution to the Theory of Capillary Phenomena in Soil."* Journal of Agricultural Science, 1927, Vol. XVII., pp. 264-290.

This paper develops further the theory outlined in Paper No. XXVI., and deals with certain criticisms (Paper No. XXVIII.). In order to clarify the points at issue a more complete treatment is given of the ideal case for that part of the problem which has not received precise mathematical treatment. The pressure deficiency produced by capillary forces in the soil water has been directly measured for several simple materials approximating to the ideal case. The results are shown to be confirmatory of the theory and to throw considerable light on the problem of capillary rise in soils which has received so much attention from soil physicists.

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(*c*) SOIL CULTIVATION.

XXX. B. A. KEEN and W. B. HAINES. *"Studies in Soil Cultivation. I. The Evolution of a Reliable Dynamometer Technique for Use in Soil Cultivation Experiments."* Journal of Agricultural Science, 1925, Vol. XV., pp. 375-386.

This paper is the first of a series representing attempts to apply exact measurement in various ways to questions of soil cultivation. It presents the results of a critical examination of the technique of dynamometer measurements when applied to cultivation processes. A description is given of the dynamometer used, which enabled simultaneous and continuous records to be obtained of draw-bar pull, and depth and speed of ploughing. Data are then given for the effect on the drawbar pull of variations in speed, depth of ploughing, slope of land, and other possible alterations in ploughing conditions. The results of the speed tests were most important in the economic aspect, since the increase of pull is only slight for considerable increase in speed. Hence there should be a great saving in costs where it is possible to increase the normal ploughing speed. The advisability is also discussed of making dynamometer comparisons, not on drawbar pull alone, but on the basis of power factor, which includes this question of the time occupied.

The other main conclusion which is established by this critical survey is that if the implemental factors are kept constant, then the values of drawbar pull during ploughing are closely related to the locality of the field. In other words the soil variations are reflected in the drawbar pull, so that the records for the ploughing of two contiguous furrows show a close similarity in outline.

XXXI. W. B. HAINES and B. A. KEEN. *"Studies in Soil Cultivation. II. A Test of Soil Uniformity by Means of Dynamometer and Plough."* Journal of Agricultural Science, 1925, Vol. XV., pp. 387-394.

Following up the main conclusion reached in the last paper, the idea was developed of using the dynamometer and plough as a soil surveying instrument for field use. The drawbar pull is taken as a measure of the physical properties of the soil at the point concerned, so that by properly spacing the measured furrows across a field, a complete soil map can be prepared showing the variations in the physical properties of the soil. The map is best prepared by drawing lines through regions of equal drawbar pull, similar to contour lines of height in an ordinary map. The name "Isodyne" has been adopted for lines so drawn. An isodyne map is shown for a field at Rothamsted which had not previously been under experiment and was chosen for a test of uniformity. The area of some six acres was sub-divided into plots of one chain square, and the mean drawbar pull calculated from a series of measurements. The values varied between 1,200 and 1,700 lb. at different places, with perfect definite gradients in these values between the light and heavy places. Assuming a division of the field into strips, as would be done for a competitive implement

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trial, the average pull along the strips varied by about 12 per cent. Thus such a competition would be subject to a heavy unknown handicap unless the field had first been explored and the handicap assessed.

Preliminary measurements are also discussed, which show that the drawbar pull has a positive correlation with the clay content of the soil, and that there is a negative correlation with the number of wheat plants which were growing on the plots in early spring.

XXXII. W. B. Haines and B. A. Keen. *"Studies in Soil Cultivation. III. Measurements on the Rothamsted Classical Plots by Means of Dynamometer and Plough."* Journal of Agricultural Science, 1925, Vol. XV., pp. 395-406.

This paper presents and discusses the isodyne maps which have been obtained for the permanent wheat, barley and mangold plots at Rothamsted, viz., Broadbalk, Great Hoos, and Barnfield.

The most intensive work has been done on Broadbalk, and the results for various years, when compared together, show complete permanence in the features brought out by these maps.

The measurements show that the drawbar pull is related to the clay content of the soil and also to the drainage rates. On a particular occasion the rate of efflux of drainage water was measured for each plot, and a high positive correlation was shown with the average drawbar pull for the plots. Thus the drainage was largest in amount for the heaviest plots, showing the greater need for artificial drainage on those plots having the heaviest soil.

The isodyne map for Great Hoos permanent barley has no special feature except that it has greater uniformity than any other area yet examined on this farm.

The map for the permanent mangold plots on Barnfield shows large variations in the soil, and opens up a new problem in the high values obtained on the farmyard manure strip. It is contrary to all other measurements and experience that a plot having this treatment should be heavy to work. Part of the reason was found to lie in a high moisture content, but in the main the explanation of this anomalous behaviour must be sought along physico-chemical and biological lines.

XXXIII. E. M. Crowther. *"Some Aspects of the Gezira Soil Problem (and Analysis of the Influence of Rainfall on The Yield of Cotton at the Gezira Research Farm."* Report of a Meeting in the Sudan Gezira, in December, 1925, for the discussion of certain problems connected with cotton growing. Sudan Government, Khartoum, 1926, pp. 18-28.

This contribution to a joint discussion on the problems arising in the cultivation of cotton by irrigation on the heavy alkaline soils of the Gezira, is based on physical and statistical investigations made whilst the author was working temporarily at the Gezira Research Farm, Wad Medani, Sudan. The soil of the Gezira has a hard layer at a depth of about 3 feet, and it is known from field studies of water movement after irrigation,

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that but little of the added water percolates below this depth. Cotton roots, exposed by washing away the soil with a jet of water, did not penetrate this layer but were confined to the first two feet of soil. Measurements of the apparent specific gravity of soil by the waxed block method were made at a series of depths down to 4 feet. The density of the moist soil increased from 1.65 gms. per cc. at the surface to a maximum value of 1.80 gms. per cc. at about 3 feet (the weight of dry soil in gms. per cc. increased from 1.29 to 1.49). The high value at 3 feet shows that the closeness of packing of the soil particles is one factor in the hardness and impermeability of this layer. But even when this factor is removed by uniform packing of sieved soils in columns in the laboratory, there are marked differences in permeability in samples taken from different depths. The rate of movement of water decreased steadily from the surface to very low values in soils taken from the third foot; below this depth the rate of movement increased owing to the flocculating action of the sodium sulphate present. The possibility of increasing the permeability of the field soils by cultivation methods was discussed and attention drawn to the desirability of investigating the effects of delaying the cultivation of the fallow preceding the cotton crop.

Data for the yields of cotton on the older experimental areas in the Gezira were subjected to a statistical analysis. In any one year the yields of cotton grown under miscellaneous rotations at Tayiba from 1911 to 1922 decreased steadily for each additional crop of cotton previously grown on the plot. It has been suggested that this deterioration may arise from the intrinsically bad effect of water on a saline soil. Except in the earliest years the yields were not diminished by the previous growth under irrigation of other crops, chiefly lubia and dura. These crops appear to counteract the deleterious effect of irrigation, probably by the introduction of organic matter or the fixation of nitrogen. In rotation experiments at the Gezira Research Farm, the deterioration is least in the rotations including the leguminous crop, lubia. The correlations between the monthly distribution of rainfall and the yields of cotton in five rotation experiments at the Gezira Research Farm for the period 1918 to 1925, were investigated. For the normal three year rotation, lubia, fallow, cotton, there was a striking agreement between low yields and high early (May and June) rainfalls. ($r = -0.94$). Two year rotations and continuous cotton did not show this effect, but the yields were connected with the rainfall at other periods. Thus late rains (September and October) had a bad effect, which increased in magnitude for the rotations in the order, fallow—cotton, dura-cotton, lubia—cotton, continuous cotton; the bad effect of late rains increased as the duration of the fallow preceding the cotton crop decreased. This probably indicates the importance of the fallow in increasing the permeability of the soil to water.

Some support was given to the conclusions from the three course rotations by the results from three course rotations at Tayiba and Barakat. Each of these estates had 2,000 acres of cotton annually during the six years for which the local rainfall data were available. The correlation coefficients between yield and May and June rainfall were —0.81 and —0.50. No satisfactory explanation of this effect could be offered, but the hypothesis

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was advanced that the bad effect of early rains arises from a loss of available nitrogen from soils containing very little decomposable organic matter during heavy rains in July and August when these have been preceded by an early rainfall sufficient to allow nitrification during May and June. In two-course rotations the presence of decomposable organic matter would probably reduce this loss just as in humid climates the introduction of bulky organic matter and stubbles reduces the loss of nitrate during the winter months.

It was concluded from a consideration of the rotation and manurial experiments at the Gezira Research Farm and from general observations that, after the water supply, the most important soil factor in the growth of cotton in the Gezira was the nitrogen supply.

(*d*) PHYSICAL CHEMISTRY AND INORGANIC CHEMISTRY.

XXXIV. A. N. PURI. *"Some Experiments on the Interaction between Soil and Dilute Acids."* Journal of Agricultural Science, 1925, Vol. XV., pp. 334-342.

The conditions of equilibrium between soil (free from carbonates and absorbed bases) and dilute acids, was studied, and also the degree to which soil can remove anions from solution in conditions which render improbable the formation of insoluble salts.

The equilibrium between the soil and each of several dilute acids employed, can be expressed by Freundlich's equation, and it may be concluded that the interaction is a surface phenomenon.

The soil was capable of removing chlorine ions from hydrochloric acid solution.

XXXV. H. J. PAGE. *"The Nature of Soil Acidity."* Transactions of the II Commission of the International Society of Soil Science, Vol. A., Groningen, 1926, pp. 232-244.

A discussion of the nature of soil acidity in the light of modern views on the ionic exchange relationships of the soil colloids. The views of Kappen, who distinguishes four different types of soil acidity, are criticised. It is maintained that the conception of the absorbing complex of the soil as consisting of an insoluble colloidal acid, or "acidoid," with which are associated surface-active hydrogen and basic cations, brings into line the majority of the known physico-chemical properties of the soil. The different types of acidity postulated by Kappen can all be regarded as manifestations of the same property of the complex, namely, the tendency of metallic cations to exchange with hydrogen ions as well as with other cations.

XXXVI. C. E. MARSHALL. *"Some Recent Researches on Soil Colloids. A Review."* Journal of Agricultural Science, 1927, Vol. XVII., pp. 315-332.

A critical review of recent work on the nature and physico-chemical properties of the colloids of the soil.

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XXXVII. H. J. PAGE and W. WILLIAMS. *"The Effect of Flooding with Sea Water on the Fertility of the Soil."* Journal of Agricultural Science, 1926, Vol. XVI., pp. 551-573.

The flooding with sea-water of land around the Humber in 1921 spoilt a considerable area of arable land.

The effects of the flooding, which consisted chiefly in an entire destruction of the tilth of the soil, are described, and compared with the recorded effects of similar floods in Holland and in Essex.

The results of an examination of the exchangeable bases in the flooded soil are considered in the light of modern work on the relation between the nature of the exchangeable bases in the soil and its physical condition. It is shown that the observed effects can be explained by replacement of a considerable proportion of the exchangeable calcium of the soil by sodium.

Dutch experience on the reclamation of flooded soils is discussed. It is shown that in the first few years after flooding, the land should be cultivated as little as possible.

The use of lime or gypsum for the treatment of flooded soils, in order to hasten the restitution of calcium to the clay in place of sodium, is discussed. From an examination of the soil from plots which had been treated with these materials, it is shown that, although both produced in some degree the desired effect chemically, the action did not proceed far enough in 12 months to produce a noticeable improvement in the tilth.

It may be possible under favourable conditions to grow certain arable crops on flooded land, among which crucifers appear to be specially suitable.

However, the most satisfactory and promising means of hastening the recovery of tilth and fertility by flooded land appears to be the establishment of a ley of lucerne, clover, or "seeds" which can be left down for several years.

(*e*) BIOCHEMISTRY AND ORGANIC CHEMISTRY.

XXXVIII. H. J. PAGE. *"Studies on the Carbon and Nitrogen Cycles in the Soil. I. On the Nature and Origin of the Humic Matter of the Soil."* Journal of Agricultural Science, (in the press).

This paper is the first of a series dealing with investigations carried out in the last few years by or under the direction of the author. It is shown from the results reported in detail in the next four papers of the series, (1) That the humic matter of the soil is of a similar character in soils of widely different organic carbon content brought about by different manurial and cultural treatments. (2) That this can be explained on the assumption that humic matter is derived from one common constituent of plant residues, the remaining constituents not contributing directly to the formation of humic matter. (3) That the quantitative study of the humification of plant materials and the comparison of various artificial "humic acids" with humic acids isolated from natural sources, are both in favour of the hypothesis that this common constituent of plant residues, the parent substance of humic matter, is lignin.

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These results support the lignin hypothesis of the origin of humic matter and coal, put forward by Fischer and Schrader. This hypothesis and other recent rival hypotheses on the nature of the humification process, are discussed.

XXXIX. C. W. B. Arnold. *"Studies on the Carbon and Nitrogen Cycles in the Soil. II. The Fractionation of the Organic Matter of the Soil."* Journal of Agricultural Science, (in the press).

By treatment of the soil from the plots on Broadbalk and Barnfields receiving dung artificials and no manure respectively, with cold 2 per cent. caustic soda, and with the same reagent at 100°C., it is shown that the organic carbon can be fractionated into three parts thus: (1) Material soluble in cold dilute alkali; (2) material which will not dissolve in dilute alkali until it is heated; (3) material which is insoluble in cold or hot dilute alkali. The quantitative distribution of the organic carbon among these groups is practically the same for all the soils examined.

XL. M. S. du Toit and H. J. Page. *"Studies in the Carbon and Nitrogen Cycles in the Soil. IV. A Quantitative Study of the Humification of Certain Plant Materials."* Journal of Agricultural Science, (in the press).

The rate of disappearance of the chief organic constituents of some plant materials: straw, maize cobs, sawdust, and clover hay, during their rotting under the influence of soil organisms, has been studied. It is shown that the formation of humic matter is more closely related to disappearance of lignin than to that of the other constituents. Moreover, pure preparations of those other constituents (cellulose, starch, xylan, xylose, glucose and protein) were wholly or largely destroyed by the microorganisms of the soil, without the production of any humic matter.

XLI. M. S. du Toit and H. J. Page. *"Studies in the Carbon and Nitrogen Cycles in the Soil. V. On the Preparation and Properties of Various Natural and Artificial Humic Acids."* Journal of Agricultural Science, (in the press).

The preparation and purification of humic acid from various natural sources is described. The products were compared with preparations of the various types of artificial humic acid by conductometric titration with ammonia. All the natural products behaved as true acids, producing a definite increase in the conductivity of added ammonia. The artificial humic acids from lignin and from hydroquinone, and to a lesser extent, from cellulose, resembled the natural products in this respect, but those produced from sucrose and from furfural behaved differently, causing a reduction in the conductivity of ammonia. Quantitative studies of the humification of furfural and of w-hydroxymethylfurfural *in vitro*, and of the interaction of glucose with glycine and various related bodies, are also described.

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XLII. V. SUBRAHMANYAN. *"The Biochemistry of Water-logged Soils, Parts I. and II."* Journal of Agricultural Science, (in the press).

The work described in these papers constitutes the first portion of a systematic investigation into the chemical processes occurring in water-logged soils. This is a subject of great importance in relation to tropical agriculture, in particular, for rice growing. Part I deals with the influence of water-logging on the different forms of nitrogen, on the reaction, on gas production, and on bacterial numbers. The only prominent change in the nitrogen compounds is an increase in the ammonia, which causes a slightly more alkaline reaction. The absence of appreciable carbon-dioxide production, and the lack of any increase in bacterial numbers under aerobic or anærobic conditions, suggests that the ammonia production is due to enzyme action.

Part II describes work confirming this hypothesis. It is shown that ammonia production is not hindered by the presence of an antiseptic, and that the aqueous glycerine extract of toluened soil contains an agent which is able to produce ammonia from simple protein derivatives. An active deaminase preparation, of a protein like nature was isolated. The presence of this deaminase in cultures of soil organisms was demonstrated, and its action on a number of amino-acids was studied. It is concluded that this enzymatic deaminisation may play an important part in plant nutrition on waterlogged soils.

(*f*) CHEMICAL ANALYSIS.

XLIII. C. W. B. ARNOLD. *"Studies on the Carbon and Nitrogen Cycles in the Soil. III. The Determination of Organic Carbon in Soils and Soil Extracts."* Journal of Agricultural Science, (in the press).

A description of the methods of analysis developed for use in the work described in the paper, No. XXXIX.

XLIV. V. SUBRAHMANYAN. *"An Improved Method for the Determination of Dissolved Oxygen in Water."* Journal of Agricultural Science, (in the press).

This paper deals with methods which have been specially worked out for use in the investigations on waterlogged soils, described in paper No. XLII.

IV. THE SOIL POPULATION & ITS BEHAVIOUR.

(Bacteriological, General Microbiology, Mycological Departments.)

(*a*) BACTERIA.

XLV. P. H. H. GRAY. *"A Method of Staining Bacterial Flagella."* Journal of Bacteriology, 1926, Vol. XII., pp. 273-274.

A simplified method that has proved of great value in a procedure, usually attended with much difficulty, essential in bacterial diagnosis.

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XLVI. H. G. THORNTON and R. A. FISHER. *"On the Existence of Daily Changes in Bacterial Numbers in American Soil."* Soil Science, 1927, Vol. XXIII., pp. 253-259.

The daily bacterial counts published by Smith and Worden show variations which cannot be explained as being due to sampling errors. On all three media employed by them, significant positive correlations in bacterial numbers between simultaneous samples were obtained.

The similar daily fluctuation occurring in different parts of the plot show most clearly on Thornton's mineral salts medium.

Provided the manipulative technique of Smith and Worden was sufficiently uniform, the results afford evidence of the existence, in very different conditions, of daily fluctuations in bacterial numbers, similar to those observed at Rothamsted.

XLVII. H. G. THORNTON and N. GANGULEE. *"The Life-Cycle of the Nodule Organism, Bacillus radicicola (Beij), in Soil, and its Relation to the Infection of the Host Plant."* Proceedings of the Royal Society, 1926, Ser. B., Vol. XCIX., pp. 427-451.

By means of a modification of Winogradsky's staining technique, the changes in morphology of *Bacillus radicicola* in soil were followed. A regular cycle of changes was found, unbanded rods, cocci, and banded rods successively predominating in the soil. Increase in the percentage of cocci was associated with increased bacterial numbers and with the appearance of motile forms.

By modifying the liquid used to suspend the inoculum added to the soil, the time of appearance of cocci in predominance could be altered. In particular, inoculation of the soil with a bacterial suspension in milk containing 0.1 per cent. $CaH_4(PO_4)_2 + 2H_2O$, hastened the predominance of cocci and increased the percentage to which they attained.

When the centre of a petri dish of soil and sand is inoculated with a suspension of the bacteria, the latter commence, after a lag period, to spread radially at an approximate rate of one inch in 24 hours. The length of this lag period is apparently related to the time taken for cocci to predominate in the soil and is effected by the nature of the inoculating fluid. The bacteria multiply rapidly in the soil into which they have recently spread, so that the nature of the inoculating fluid also exerts an influence on bacterial numbers at a distance from the point of inoculation. Thus inoculation of the soil with a bacterial suspension in milk containing 0.1 per cent. $CaH_4(PO_4)_2 + 2H_2O$, results in a greater spreading of the bacteria through the soil and in greater multiplication at a distance from the point of inoculation than in the case when soil is inoculated with a suspension in milk alone.

Lucerne plants grown from seed inoculated with a suspension of bacteria in milk containing 0.1 per cent. $CaH_4(PO_4)_2 + 2H_2O$, showed a considerable increase in nodule numbers and in yield compared with plants from seed inoculated with a suspension in milk alone.

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This effect was confined to the deeper portions of the root and therefore increased as the plants became older and roots developed in the deeper soil. This suggests that the additional nodule formation is due to the known effect of the phosphate in increasing the spread of the bacteria.

XLVIII. N. GANGULEE. *" The Effect of Some Soil Conditions on Nodule Formation on* Crotalaria juncea. *(L)."* Annals of Applied Biology, 1926, Vol. XIII., pp. 244-255.

From pot culture experiments, it has been shown that the formation of nodules on the roots of *Crotalaria juncea* is affected significantly by variations in the texture, moisture content, and reaction of the soil, all other conditions being kept uniform. Nodule formation was increased by higher moisture content, by increased coarseness and by reduced hydrogen ion concentration.

XLIX. N. GANGULEE. *" The Organism forming Nodules on* Crotalaria juncea *(L)."* Annals of Applied Biology, 1926, Vol. XIII., pp. 256-259.

The observations recorded in this paper show that the stages which have previously been known to take place in the life cycle of *B. radicicola* from certain leguminous plants, occur also in the life cycle of the organism isolated from nodule of *Crotalaria juncea*. These changes occur both in solid and in liquid media. The coccoid bodies have been observed both in the non-motile (" Pre-swarmer ") and the motile (" Swarmer ") stages. These are succeeded by the short-rod stage, which eventually gives rise to the banded (vacuolated) forms. The outset and duration of these stages varies with the composition of the media.

L. N. GANGULEE. *" Studies on the Lucerne Nodule Organism* (B. radicicola) *under Laboratory Conditions."* Annals of Applied Biology, 1926, Vol. XII., pp. 360-373.

It is observed that on whatever media the organism is growing, whether in liquid or agar or in soil, the various stages of the life-cycle are found to occur simultaneously, but in varying proportions. The soil conditions, such as aeration, temperature, and the presence of certain salts, are among the factors that determine which of the stages shall be in predominance. The relative efficiency of liquid and solid media in bringing about the predominance of a particular form was also studied.

In the main, the existence of the five stages in the life-cycle of the organism observed by Bewley and Hutchinson is confirmed; but evidence is obtained to show that under very favourable conditions the motile cocci (" swarmer ") can emerge directly from the banded rod stage, developing flagella even before their emergence, and therefore missing out the non-motile (" pre-swarmer ") stage.

The appearance of coccoid bodies was accelerated in the presence of saccharose, mannite and phosphates (in agar media), and also in soil extract alone. Short rods are elongated cocci, and they tend to persist in media containing the ingredients mentioned above.

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(*b*) PROTOZOA.

LI. D. W. CUTLER and L. M. CRUMP. *"The Influence of Washing upon the Reproductive Rate of* Colpidium colpoda." Biochemical Journal, 1926, Vol. XIX., pp. 450-453.

The rate of reproduction of *Colpidium colpoda* under various external conditions was described in earlier papers, summarised in the previous report of this station. The present paper gives the results of experiments carried out to test the contention of Prof. T. Brailsford Robertson that a preliminary washing of the organisms before isolation would have modified the results previously obtained.

It was found, however, that this was not the case, no retardation of the reproductive rate being observed.

LII. D. W. CUTLER and D. V. BAL. *"Influence of Protozoa on the Process of Nitrogen Fixation by* Azotobacter chroococcum." Annals of Applied Biology, 1926, Vol. XIII., pp. 516-534.

Increased nitrogen fixation by *Azotobacter chroococcum* in the presence of protozoa has been shown to occur, as previously described by Nasir (Annals of Applied Biology, Vol. X., pp. 122-133).

There is a definite relationship between the efficiency of the strain used, the incubation period, and the concentration of mannitol used.

The feeding action of *Colpidium colpoda,* and *Hartmanella hyalina* on Azotobacter has been demonstrated.

The reason for increased nitrogen fixation appears to be due to the efficiency of Azotobacter being maintained for a longer period as a result of the feeding action of the protozoa, together with the conservation in the bodies of the protozoa of the nitrogen fixed by the bacteria on which the protozoa have fed.

LIII. D. W. CUTLER. *"Methods in Soil Protozoology."* Abderhalden's Handbuch der Biologischen Arbeitsmethoden, Urban and Schwartzenberg, Berlin.

An account is given in German of the modern technique used for the study of soil protozoa.

LIV. H. SANDON. *"The Methods and Present State of the Study of Soil Protozoa."* Uspiechin Biologitsheskieh Nauk, 1927.

In this paper a detailed account of the present day technique of soil protozoology is given, together with a brief description of the more recent developments of the subject. It forms one of a series of papers on the modern methods of soil research, edited by Professor Omelianski for the benefit of investigators in Russian-speaking countries.

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(c) FUNGI.

LV. F. CHODAT. *"Recherches Expérimentales sur la Mutation chez les Champignons."* Bulletin de la Société Botanique de Genève, 1926, Serie 2, Vol. XVIII., pp. 41-144.

Out of over 80 species of fungi grown in culture in order to observe the relative occurrence of genetic instability, two species, *Aspergillus ochraceus* and *Phoma alternariacearum* were selected for detailed study.

Aspergillus ochraceus.—From single-spore cultures, two strains of this fungus were obtained, one the original yellow form and the other, originating as a sector, a dwarfed form, producing a red colour in the medium. These types proved to be constant for many generations over a long period. Morphologically, the two forms were distinct in several characters. The physiological properties of the fungi were examined in detail and correlations were found between the factors—amount of nitrogen and carbon in the medium, the pH of the latter and the production of the red colouring matter. The growth of the parent form was greater than that of the variant on media poor in nitrogen, the latter requiring more nitrogen to produce less growth. This difference was correlated with the fertility of the yellow strain and the partial sterility of the red strain.

Phoma alternariacearum.—From single spore cultures, five distinct forms of this species were ultimately obtained, which remained constant for many generations. A study was made of the morphological, physiological and biometric differences between these forms and general relations found to hold between biometric and cultural data were traced to physiological causation.

The interpretation of the variations observed is discussed in relation to previous work on fungi.

LVI. WM. B. BRIERLEY. *"Variation in Fungi and Bacteria."* Transactions of the International Congress of Botany, Ithaca, U.S.A., 1926. In the Press.

An introductory review of the sources of information regarding the present status of the genetics of micro-organisms is followed by a critique of genetic phenomena, concepts and terminology in groups of organisms other than bacteria and fungi. These latter groups are considered in relation to the various methods which may be adopted of classifying genetic data. An outline schedule is presented in which a considerable number of data on variation in fungi and bacteria are arranged according to the time and mode of origin of the variants, their constancy and relation to environmental conditions and their relation to prior and succeeding generations.

LVII. R. D. REGE. *"Biochemical Decomposition of Cellulosic Materials with Particular Reference to the Action of Fungi."* Annals of Applied Biology, 1927, Vol. XIV., pp. 1—44.

Two factors appear to control the decomposition of ripe cellulosic material in presence of available nitrogen. One, the

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food or energy factor, is usually represented by pentosans; the other, or inhibitory factor, is always lignin. The predominance of the former over the latter determines the ease of decomposition. The results now obtained confirm the view put forward in 1924 that any cellulosic material containing 30 per cent. of pentosan and a relatively small amount of woody fibre can be converted easily into an organic nitrogenous manure. The prediction of the "decomposibility" of a material is thus possible.

Attempts to increase the ratio of energy to inhibitory factor in resistant materials by the addition of carbohydrates proved unsuccessful. It was concluded that since micro-organisms obtained their food materials outside the tissues, they did not attack the tissues until the more easily available food-stuffs were exhausted. Thus the decomposition of the material was actually less than was possible under natural conditions.

Mannose and galactose do not appear to form suitable food for the micro-organisms concerned in these processes, and it is concluded that the pentosan part of the hemi-celluloses is most important as microbial food. Incidentally, it is shown that Kröber and Tollens' method for determining pentosans is untrustworthy and a modification is suggested.

A study of the relative importance of bacteria and fungi proves that, under the conditions of these experiments, most of the work is done by fungi. The high temperature (70° C.) often reached by manure heaps is above the range of such organisms as *Spirochæta cytophaga,* but one of the fungi now isolated flourishes at 50° C. and upwards.

(*d*) ALGÆ.

LVIII. B. Muriel Bristol Roach. *"On the Relation of Certain Soil Algæ to some Soluble Carbon Compounds."* Annals of Botany, 1926, Vol. XI., pp. 149-201.

A method is described for obtaining pure cultures of algæ from the soil.

In pure cultures of soil algæ on solid media, the great majority of species show greatly increased growth in the presence of a number of different soluble organic compounds, each species having its own order of selection of the compounds that have been tested; a few species do not behave in this way, and are possibly completely autotrophic in nutrition.

Pure cultures of several soil species in liquid media containing glucose showed that the best estimate of the growth of a unicellular alga may be obtained by making daily measurements of the average size of the cells and of the number of cells per unit volume of liquid, and by calculating from these data the bulk of algal protoplasm present. The logarithmic values of the bulk when plotted against time lie upon a straight line within the limits of experimental error for a limited period of growth; the slope of this line (i.e., the tangent of the angle which it makes with the horizontal axis) may be taken as a measure of the rate of growth of the organism in the given medium.

The growth of the alga *Scenedesmus costulatus, Chod., var. chlorelloides, nov. var.*, has been studied quantitatively in liquid

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media containing mineral salts and 1 per cent. of certain soluble organic compounds. In the glucose medium, the degree of variance of the observed values (logarithmic) from the calculated straight line of nearest fit is shown to be greatly reduced by rigorous control of light and of temperature, and by continuous aeration of the medium. In this medium the organism is able to grow in the dark, retaining its green colour. There is some reason to believe that the rate of growth in the dark may be approximately equal to the difference between its activities in the light in the same medium and in that with mineral salts alone. In certain media containing substances less favourable to the growth of the organism, the degree of deviation of the observed values from the straight line is greater than in the glucose medium. With maltose there appears to be an initial "lag" period preceding the straight-line period of growth. In mannite there are conspicuous fluctuations in the growth rate due to death of the young cells. Xylose is completely toxic to the organism under the conditions observed.

The relative average rates of growth in the different media may be expressed quantitatively, as follows: Glucose in the light 100 per cent., maltose 100 per cent. preceded by a "lag" period, galactose 94 per cent., sucrose 84 per cent., fructose 73 per cent., mineral salts alone 60 per cent., glycerine 43 per cent., glucose in darkness 40 per cent., mannite 13 per cent., xylose 0 per cent.

In those media that are completely favourable to its growth, the increase in bulk of *Scenedesmus costulatus, Chod., var. chlorelloides,* follows the same laws as a simple exponential curve, for a limited period of time.

LIX. B. Muriel Bristol Roach. "*Methods for Use in Studying the* Algæ of the Soil." in Abderhalden—Handbuch der biologischen Arbeits-methoden, 1926.

Details are given of a cultural method for estimating roughly the numbers of algæ (Chlorophyceæ and Diatoms only) in the soil. Methods are also described for the isolation and cultivation of soil algæ in (*a*) impure and (*b*) pure cultures, and suitable media are recommended for use. An account is given of a special method for estimating quantitatively the effect of any condition or chemical compound on the rate of growth of a unicellular soil alga, the rate of growth being regarded as an index of the metabolism of the organism.

Methods are also described for studying the biochemical activities of pure cultures of algæ under the following headings:— (1) Decomposition of protein (gelatine); (2) Fixation of nitrogen; (3) Transformation of insoluble mineral substances into soluble forms.

V. THE PLANT IN DISEASE; CONTROL OF DISEASE.

(Entomological, Insecticides and Fungicides, Mycological Departments.)

(*a*) INSECT PESTS AND THEIR CONTROL.

LX. W. M. Davies. "*On the Tracheal System of Collembola with Special Reference to the Species* Sminthurus viridis." Quarterly Journal of Microscopical Science, 1927, Vol. CXXI., pp. 15-30.

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No extensive study of the tracheal system of Collembola has previously been made. The general plan of the tracheæ has been worked out on *Sminthurus viridis*; two independent systems exist. The presence of only a single pair of spiracles constitutes a unique condition among adult insects. The position of these is in the anterior region of the prothorax and not in the head as previously believed. The structure of the spiracles is extremely primitive and they possess no closing apparatus. The tracheæ branch dichotomously, but no anastomosis exists between the systems of the two sides of the body. Tænidia are present, but no "transition cells" have been observed, and the fine tracheæ terminate in unbranched tracheoles. The initial entrance of air into the tracheæ is through the spiracles; the displacement of fluid is very slow and the whole system is not completely filled with air until about 14 days after emergence from the egg. Tracheæ are found to be a constant feature in all members of the Sminthurinæ examined. Various methods of technique adopted are given.

LXI. W. M. Davies. *"Collembola Injuring Leaves of Mangold Seedlings."* Bulletin of Entomological Research, 1926. Vol. XVII., pp. 159-162.

Damage to seedling mangolds due to the Collembolan *Bourletiella hortensis* Fitch is occasioned by the insects collectively perforating the leaves and the excessive bleeding that ensues. In the particular infestation studied the number of insects per acre worked out at about 1,500,000. Other hosts of the same insect were found to include groundsel, goosefoot and red-shank. During dry weather the insects were most numerous in early morning when the leaves are moistened with dew. Control methods were tested, including the trailing of paraffin-soaked sacks over the crop. The repellent effect of the paraffin proved evanescent owing to rain, and the dragging of tarred sacking hung between two wheels which were fastened together with long cross-bars was resorted to. By taking advantage of the leaping powers of the insect in this way the method proved completely successful, and enormous numbers of Collembola were trapped on the adhesive surface of the tar. No further control measure appears necessary, and a permanent movable contrivance, that can be used whenever occasion demands, is described and figured.

LXII. J. Davidson. *"Biological Studies of* Aphis rumicis Linn. *Factors Affecting the Infestation of* Vicia faba *with* Aphis rumicis." Annals of Applied Biology, 1925. Vol. XII., pp. 472-507.

Experiments were carried on during four years under controlled experimental conditions, and lead to the following conclusions.

Temperature influences the developmental period of the aphids and the number of young produced daily, thereby affecting the number of aphids produced in a given time.

On beans grown in sand watered with tap water fewer aphids developed in a given time than on beans grown in sand watered with normal culture solution, indicating a nutrition effect on the aphids.

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On beans grown in sand watered with normal culture solution an increased number of aphids developed in a given time compared with beans grown in soil watered with the same solution, indicating the effect of the soil medium on the plant and the nutrition factor for the aphis.

Beans grown under varying daylight intensity gave varying degrees of increase in the number of aphids in a given time, indicating again a nutrition effect on the aphids in that the least number developed on the plants receiving the least amount of daylight.

On beans which were young and had not reached the flowering stage when infected in June the number of aphids which developed in a given time was 50 per cent. greater than on bean plants which were six weeks older and were setting pods.

On certain varieties of field beans the number of aphids which developed in a given time varied considerably, indicating that some varieties were more susceptible to infestation than others.

LXIII. J. DAVIDSON. *"On the Occurrence of Parthenogenetic Intermediates in* Aphis rumicis L. *and Their Relation to the Alate and Apterous Viviparous Females."* Journal of the Linnean Society (Zoology), 1927. Vol. XXXVI., pp. 467-477.

During rearing experiments with *Aphis rumicis* 21 viviparous forms have been recorded which exhibit morphological characters intermediate between the apterous and alate parthenogenetic, viviparous females. Certain of these forms were reared and, in their behaviour, as regards the offspring they produced, they resembled the apterous members of the same generation rather than the alate members. The evidence obtained indicates that the occurrence of apterous forms in the parthenogenetic generations of this species is influenced by certain physiological conditions.

LXIV. J. DAVIDSON. *"The Sexual Parthenogenetic Generations in the Life Cycle of* Aphis rumicis L." III International Entomological Congress, Zurich, 1925, Vol. II., pp. 452-457.

A single strain of the black bean *Aphis rumicis* L. has been reared for 4 years on broad beans (Vicia faba) with the spindle tree (*Euonymus europæus*) as the winter host. Sexual forms were obtained on beans and on Euonymus and eggs were laid on both plants, but preferably on Euonymus. Sexual females and males appeared in the colonies on various dates from September to May, but no sexual forms were recorded during the period June to September. Certain individuals in the colonies continued parthenogenetic reproduction in the greenhouse throughout each winter and in addition sexual forms developed on various dates. The period in which the sexual forms developed indicates an adaptation to a periodic seasonal rhythm and factors of temperature associated with plant growth (nutrition) exert an influence by favouring or restricting their appearance.

LXV. C. T. GIMINGHAM. *"On the Presence of an Egg-burster in Aphididæ."* Transactions of the Entomological Society, 1925, pp. 585-590.

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The eclosion of the embryo fundatrix of *Amphorophora lactucæ,* Kalt. from the winter egg is described and the presence of an egg-burster noted. The organ is seen as a dark brown chitinous toothed ridge over the vertex of the head and extending backward as far as the eyes; it is attached to an embryonic membrane and is left behind with this membrane on complete emergence of the young insect. Similar structures were found on embryos of *Phorodon humuli,* Schr. and *Aphis pomi,* DeG.

LXVI. F. TATTERSFIELD, C. T. GIMINGHAM and H. M. MORRIS. *" Studies on Contact Insecticides. Part IV. A Quantitative Examination of the Toxicity of Certain Plants and Plant Products to* Aphis rumicis, L. (*The Bean Aphis*)." Annals of Applied Biology, 1926. Vol. XIII., pp. 424-445.

An account is given of laboratory experiments on the toxicity to *Aphis rumicis* L. of extracts of a considerable number of plants, including some tropical fish-poisons, Lupins, Broom, Gorse, Lobelia and others.

Alcoholic extracts of certain tropical plants used as fish-poisons are shown to have a high toxicity under the conditions of the experiments. The roots and stems of White Haiari, and the stems of Black Haiari (both species of *Lonchocarpus* from British Guiana), the roots of *Tephrosia toxicaria* and the leaves of *T. vogelii,* all possess notable insecticidal properties. The roots and stems of *T. candida* are less toxic.

Preliminary experiments indicate that the Haiaris and *T. vogelii* and *T. toxicaria,* when tested as stomach poisons, exert both a repellent and toxic action to caterpillars.

Certain derivatives isolated from these plants were tested. The most toxic substance obtained from the Haiaris is shown to be identical with tubatoxin, the crystalline poison found in *Derris elliptica.* Tubatoxin proved to be several times more toxic than nicotine. In the case of *Tephrosia vogelii* and *T. toxicaria,* the most toxic substance isolated was resinous in nature. Crystals closely corresponding to tephrosin, as isolated by Hanriot, were less toxic.

A number of alkaloids was also investigated, Cytisine and lobeline, known to have a physiological action similar to that of nicotine, were found somewhat less toxic than nicotine to aphides. Eserine was the only other alkaloid tested which approached nicotine in toxicity.

LXVII. C. T. GIMINGHAM, A. M. MASSEE and F. TATTERSFIELD. *" A Quantitative Examination of the Toxicity of* 3 : 5-*Dinitro-o-cresol and Other Compounds to Insects' Eggs, under Laboratory and Field Conditions."* Annals of Applied Biology, 1926. Vol. XIII., pp. 446-465.

The toxicity of 3 : 5-dinitro-o-cresol and its sodium salt to eggs of the moth, *Selenia tetralunaria* Hüfn, has been determined quantitatively under controlled conditions in the laboratory. The figures obtained confirm earlier results and show (a) that these compounds have a very high toxicity to insect eggs, and (b) that

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the sodium salt of dinitro-o-cresol is only slightly less toxic than dinitro-o-cresol in the uncombined state.

Preliminary work indicates that dinitro-o-cresol is also highly toxic to insect eggs of a more resistant type than those of *S. tetralunaria.*

Spray fluids containing dinitro-o-cresol or the sodium salt showed a high efficiency against eggs of the Hop-Damson Aphis (*Phorodon humuli* Schr.) on plum trees on a larger scale under field conditions. The trees sprayed with these compounds remained almost free from aphids during the following spring when the control trees were badly infested.

A quantitative method for judging the results of the field experiments was worked out. This involved recording details of large numbers of eggs on selected shoots on sprayed and control trees before and after spraying, a numerical measure of the effect of the various treatments being thus obtained. The method gave consistent and reliable results.

The spray fluids containing dinitro-o-cresol and its sodium salt had a marked cleansing effect on the trees. No injury to the trees was observed.

LXVIII. D. M. T. Morland. *"On the Microscopic Examination of Bees for Acari."* Annals of Applied Biology, 1926. Vol. XIII., pp. 502-505.

The discovery by Rennie and his collaborators of the mite which causes one form of adult bee disease, renders desirable a quick method of dissection to facilitate detection of the parasite. The method described allows of the whole of that portion of the thoracic tracheal system which is liable to invasion by the mite to be exposed to view.

(*b*) FUNGUS PESTS AND THEIR CONTROL.

LXIX. W. A. Roach and W. B. Brierley. *"Further Experiments on the Use of Sulphur in Relation to Wart Disease of Potatoes."* Annals of Applied Biology, 1926. Vol. XIII., pp. 301-307.

Plots of light sandy soil at Ormskirk carefully fenced in to prevent re-contamination were treated with sulphur at rates of 10 cwts. and 15 cwts. per acre. The sulphur was incorporated by means of the " Simar " Rotary Tiller, kindly loaned by the Piccard Pictet Company. A planting of King Edward and a re-planting of Arran Chief varieties in the treated plots almost completely failed to grow. On the few plants which developed, Wart Disease was present in less quantity than on the plants in the untreated controls.

A plot of heavy clay soil at Hatfield was treated with 3 tons of sulphur per acre incorporated by means of the Simar Rotary Tiller. Plants of King Edward variety grew well, but showed a considerable amount of wart disease.

Plots of land at Ormskirk which in 1924 had received amounts of sulphur varying up to one ton per acre were in 1925 given a dressing of lime and planted with Majestic variety of potatoes. No effect of the previous treatment on the crop was apparent.

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LXX. Mary D. Glynne. *"Wart Disease of Potatoes: The Development of* Synchytrium endobioticum *(Schlib.)* Perc., *in 'Immune' Varieties."* Annals of Applied Biology, 1926. Vol. XIII., pp. 358-359.

By an infection method previously described small protuberances and surface irregularities were obtained on the shoots of six different "immune" varieties of potato. These did not seem to develop further or to produce ordinary warts, but microscopic examination showed that infection by *Synchytrium endobioticum* had taken place. Its development up to the liberation of the summer sporangia has been observed, but its further development, that is reinfection by zoospores from summer sporangia and the formation of winter sporangia, has not been detected.

LXXI. Mary D. Glynne. *"The Viability of the Winter Sporangium of* Synchytrium emdobioticum *(Schilb.)* Perc., *the Organism Causing Wart Disease in Potato."* Annals of Applied Biology, 1926. Vol. XIII., pp. 19-36.

A staining method for testing the viability of the winter sporangia of *Synchytrium endobioticum* is described. The sporangial contents are pressed out into acid fuchsin or after treatment by a strongly alkaline reagent into methylene blue. The staining reactions have been correlated with the results of infection experiments in pots. Sporangia which, like the controls, stain faintly, produce a high percentage infection and are therefore alive. Those which stain deeply and rapidly produce no infection and are presumably dead. There is an intermediate group in which some sporangia stain deeply and some are intermediate in reaction. This group tends to give less infection than the controls.

A method whereby sporangia which have been treated in soil may be extracted without affecting their viability is described. The method depends on the difference in specific gravity of sporangia, which has been determined as about 1.17, and of soil which is in the region of 2.5. The sporangia are extracted by means of chloroform (sp. gr. 1.5 approx.), which does not affect their viability.

A study of the relation of temperature, time and viability shows that treatment for 5 minutes at 90° C., 15 minutes at 80° C., 1 hour at 70° C., and 8 hours at 60° C., have a similar effect in killing all the sporangia.

LXXII. S. Dickinson. *"A Simple Method of Isolating and Handling Individual Spores and Bacteria."* Annals of Botany, 1926. Vol. XL., pp. 273-274.

The method described consists of holding the bacteria in a film of water and then moving one of them to another part of that film by means of a local thickening, the whole process being observed through an oil immersion lens.

In practice the film of water used is that on the surface of a layer of agar on a coverslip, while the local thickening is obtained by bringing a fine glass rod in contact with the agar, and then withdrawing it slightly, so forming a column of water; it is in the

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column so formed that a bacterium is carried to another part of the agar and that part is cut off and put into the new culture tube. The glass rod is capable of fine adjustment in all directions, being mounted on a three movement machine clamped to the microscopic stage, which is called an Isolator, being made for the purpose by Messrs. Ogilvy & Co.

With this instrument it is possible, starting from a culture, to isolate a single bacterium and transfer it to a fresh test tube in from 3—5 minutes.

LXXII. (*a*) S. DICKINSON. "*A Method of Isolating and Handling Individual Spores and Bacteria.*" Proceedings of the Royal Society of Medicine, 1926, Vol. XIX., Section of Pathology, pp. 1-4. (See preceding paper for abstract.)

LXXIII. S. DICKINSON. "*Experiments in the Physiology and Genetics of the Covered Smuts of Oats and Barley. Hyphal Fusion.*" Proceedings of the Royal Society, 1927. Ser. B., Vol. 101, pp. 126-136.

The cytology of the Covered Smuts of Oats and Barley in pure culture has been investigated, and the fusion, both within and across the species investigated between the mycelia of different "gender" derived from single sporidial isolations, is described. The fusion hypha is binucleate, and nothing has been seen which suggests that nuclear fusion occurs. The binucleate fusion-hypha gives rise to uninucleate hyphæ which are of different gender, these being produced at different ends of the fusion hypha.

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