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### Crops, Plant Growth and Fertiliser Investigations

#### Rothamsted Research

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## SCIENTIFIC PAPERS

Published 1930

### CROPS, PLANT GROWTH AND FERTILISER INVESTIGATIONS

Statistical Mycological Fermentation and Chemical  
Departments ; and the Imperial College Staff)

- I. F. E. ALLAN AND J. WISHART. "*A Method of Estimating the Yield of a Missing Plot in Field Experimental Work.*" *Journal of Agricultural Science*, 1930. Vol. XX, pp. 399-406.

In cases where a yield or other value from one plot of a field experiment is missing, a method has been developed for furnishing an estimate of the missing figure, based on all the other values. The calculation is given for experiments of the Randomised Block and Latin Square arrangements.

- II. R. A. FISHER AND J. WISHART. "*The Arrangement of Field Experiments and the Statistical Reduction of the Results, 1930.*" Imperial Bureau of Soil Science—Technical Communication No. 10, H.M. Stationery Office.

This memorandum aims at explaining the principles underlying the field experimental technique recently elaborated at Rothamsted, and gives, with appropriate illustrations from actual experiments, the full arithmetical working involved in the statistical reduction of the data. The memorandum stresses two points of importance: (1) the desirability of uniformity of procedure, and (2) the necessity for a field technique which shall minimize experimental errors, and at the same time provide for an estimate of these errors by valid statistical methods.

- III. J. WISHART AND W. A. MACKENZIE (TYRRELL). "*Studies in Crop Variation VII. The Influence of Rainfall on the Yield of Barley at Rothamsted.*" *Journal of Agricultural Science*, 1930. Vol. XX, pp. 417-439.

The method elaborated by R. A. Fisher in his study of the effect of rainfall on wheat is here applied to the barley crop in Hoos Field, and curves are published showing for thirteen plots the benefit or loss to the final yield in bushels per acre due to an additional inch of rain over the average at any given period of the year. The main effects noted are these: (1) Excess of rain is beneficial to the barley crop for a short period in summer and, in the case of certain plots, over the autumn and winter period. (2) Rainfall over the six months when the barley is not in the ground is



just as important as rainfall in spring and summer, and the time at which the rain falls in winter is important. (3) The curves for 2-O and 2-A are essentially different in character from those of the other plots, and point to the important effect of excess of winter rain in reducing the yield of the plots having phosphate but no alkali salts (*i.e.*, no potash, soda or magnesia). (4) Excess of rain at time of sowing is harmful in all cases. (5) The curves of the "O" series (without nitrogen) are much flatter than those of the "A" series, which have a nitrogenous dressing in addition. (6) The indication of summer benefit is not inconsistent with the conclusions of Hooker that a cool summer is desirable for barley. (7) The farmyard manure plot 7-2 bears certain resemblances to the curve for the corresponding plot 2b on Broadbalk.

- IV. R. J. KALAMKAR. "*Studies in Crop Variation VIII. An Application of the Resistance Formula to Potato Data.*" *Journal of Agricultural Science*, 1930. Vol. XX, pp. 440-454.

In this paper a further test is made of the validity of the Resistance Formula suggested by Maskell to formulate the yield—nutrient relation in a crop. The material investigated consists of the results of the Rothamsted Potato experiment of 1929, designed to give information as to the effect on yield of applying nitrogenous, potassic and phosphatic fertilisers in various quantities. The experiment confirms the conclusions of Balmukand's paper as to the possibility of fitting the Resistance Formula to experimental data. The nitrogen constants are of the same magnitude as before, but the corresponding constants for potash cannot yet be regarded as well determined.

- V. J. WISHART. "*On the Secular Variation of Rainfall at Rothamsted.*" *Memoirs of the Royal Meteorological Society*, 1930. Vol. III, No. 27, pp. 127-137.

A detailed study of the rainfall at Rothamsted over the 76 harvest years, 1854-1929, has revealed the fact that not only have there been sensible changes in the average yearly rainfall of a similar character to those observed at other stations in England and Wales, but the distribution of rainfall throughout the year has changed. The maximum in autumn (and equally the minimum in spring) occurs significantly later to-day than was the case 76 years ago, but there is some sign that this movement is now reversing its direction, as appeared to have happened towards the end of the eighteenth and again in the middle of the nineteenth centuries, as judged from early records at a number of other stations.

- VI. S. H. JENKINS. "*The Determination of Cellulose in Straws.*" *Biochemical Journal*, 1930. Vol. XXIV, 1429-1432.

Cellulose in straws may be readily determined by treating the straw with hot dilute alkali and mineral acid, and then with cold alkaline hypochlorite solution. The new method gives results which are practically identical with those obtained by the Cross and Bevan procedure. The advantages of the hypochlorite method are



that 12 to 16 determinations per day can be carried out by one worker, and large scale preparations of the cellulose in straws may be made without inconvenience.

- VII. A. G. NORMAN. "*The Biological Decomposition of Plant Materials. I. The Nature and Quantity of the Furfuraldehyde-yielding Substances in Straw.*" *Biochemical Journal*, 1929. Vol. XXIII, pp. 1353-1366.

A method is given for determining the content of hemicelluloses in a plant tissue. Figures quoted for "pentosan" obtained by use of the Krober factor are unreliable because of the hexose and uronic acid groups in the hemicelluloses, and the furfuraldehyde-yielding groups intimately associated with the cellulose. If allowance be made for these and for the pectin present, a valid figure may be obtained for the pentose units of the hemicelluloses. A preparation is then made of the hemicellulose of any tissue and its pentose content determined, thus giving a factor for that material.

The nature of the hemicelluloses of oat and rye straws is described and the furfuraldehyde-yielding substance associated with the cellulose in each case, shown to be xylan.

- VIII. A. G. NORMAN. "*The Biological Decomposition of Plant Materials. II. The Role of the Furfuraldehyde-yielding Substances in the Decomposition of Straws.*" *Biochemical Journal*, 1929. Vol. XXIII, 1367-1384.

The course of the decomposition of straws is followed by frequent analyses. The most prominent feature is the rapid loss of cellulose, accounting for the major part of the lost organic matter. There is a marked early loss of hemicelluloses, which is by no means complete, as certain groups are biologically less available. Subject to structural and physical variations, it is agreed that the decomposition of mature plant materials in the presence of assimilable nitrogen depends on the balance between cellulose and the available hemicelluloses on the one hand, and the resistant materials, chiefly lignin, on the other. No evidence exists for stating that the hemicelluloses are of pre-eminent importance as satisfactory decompositions have been observed in the case of straws extracted to be practically hemicellulose-free.

- IX. A. G. NORMAN. "*The Biological Decomposition of Plant Materials. Part III. Physiological Studies in some Cellulose-Decomposing Fungi.*" *Annals of Applied Biology*, 1930. Vol. XVII, pp. 575-613.

Certain fungi were isolated which, though actively attacking cellulose in straws, make only a meagre growth on cellulose agar plates. All had their optimum temperature above that usual for fungal growth; three, indeed, could develop at 50°C. The thermogenic power of the organisms individually was tested on sterile straw. A considerable and rapid rise in temperature was observed in most cases, and some rise in all. The highest temperature attained was 49°C due to *Trichoderma sp.* The period of maximum heat production was shown to correspond closely with that of rapid loss of hemicelluloses. Cellulose decomposition does not appear to result in the production of much heat. Certain combinations of organisms were tested and the theoretical differences between competitive and co-operative association defined.



- X. A. G. NORMAN AND F. W. NORRIS. "*Studies on Pectin. Part IV. The Oxidation of Pectin by Fenton's Reagent and its Bearing on the Genesis of the Hemicelluloses.*" *Biochemical Journal*, 1930. Vol. XXIV, pp. 402-409.

Pectin readily undergoes oxidation by Fenton's reagent at 30°C, yielding products giving on hydrolysis, galactose and galacturonic acid. These are probably polymers containing mainly galactose-monogalacturonic acid and galactose-digalacturonic acid. The products resemble in appearance and general properties the structural hemicelluloses, and some support is lent to the view that the hemicelluloses may be formed in nature by the protracted mild oxidation of pectin.

- XI. A. G. NORMAN AND J. T. MARTIN. "*Studies on Pectin. Part V. The Hydrolysis of Pectin.*" *Biochemical Journal*, 1930. Vol. XXIV, pp. 649-660.

Hydrolyses of pectin were carried out with hot dilute alkali and acid, and the rate of hydrolysis followed by analyses. The pectin ring seems peculiarly susceptible to the former and is very rapidly destroyed. Certain dienolic fission products of sugars are formed, and render the determination of the uronic acid content unreliable. In the course of mild acid hydrolysis there is firstly a production of pentose by simple decarboxylation of the uronic groups. Later, degradation products probably of a furan type are formed.

No conclusions as to the arrangement of the units in the pectin molecule, or as to the type of linkage involved can be drawn from hydrolytic studies owing to the production of degradation compounds interfering with analyses.

- XII. L. R. BISHOP. "*The Proteins of Barley during Development and Storage and in the Mature Grain.*" *Journal of the Institute of Brewing*, 1930. Vol. XXXVI, pp. 336-349.

The proteins of all varieties of barley behave in a similar regular manner. For each variety studied, the proteins all increase regularly with the total nitrogen content. The rates of increase of the different proteins differ—calculated as a percentage on total nitrogen the percentage of hordein nitrogen increases regularly with increasing total nitrogen content, the percentage of salt-soluble nitrogen decreases correspondingly while the percentage of glutelin nitrogen remains constant. The actual quantities of salt-soluble nitrogen and glutelin nitrogen for any given total nitrogen content differ between different varieties which consequently are characterised by them. This applies only to mature grain. In immature grain the salt-soluble nitrogen is high and the glutelin nitrogen low, a condition which has also been found to occur in partly developed grain.

The formation of the separate proteins has been followed in barley grain as it develops on the plant, and it is concluded that development of the proteins in the barley grain is essentially a synthesis of the simple compounds which enter it up to a definite equilibrium point controlled only by the total nitrogen content and the variety.



- XIII. L. R. BISHOP. "*The Nitrogen Content and 'Quality' of Barley.*" *Journal of the Institute of Brewing*, 1930. Vol. XXXVI, pp. 352-364.

An attempt has been made to summarise the factors and properties which are of value in guiding anticipations of the brewing quality of the barley in each season and district.

Soil and season are the most important factors governing yield and quality. Variety and artificial nitrogenous manures have less effect. It is suggested that the most important aspect of soil composition is the absence or presence of organic nitrogenous matter which is regarded as resulting in nitrification in summer which supplies nitrogen late in the plant's life with resultant high nitrogen grain.

These considerations and previously published statistical work on weather effects could be used to guide anticipations of yield and quality of harvest in any district and season.

After harvest judgment of yield and quality can be assisted by a knowledge of the nitrogen content and thousand corn weight from which can be predicted the amount of "extract" on malt acid "permanently soluble" nitrogen in the wort.

- XIV. L. R. BISHOP. "*The Prediction of Extract.*" *Journal of the Institute of Brewing*, 1930. Vol. XXXVI, pp. 421-434.

By a statistical study it is established beyond doubt that there is an inverse relation between the nitrogen content of barley of one variety and the extract yield of the resulting malt. An increase of extract with increase of grain size is demonstrated almost as conclusively.

The use of this relation is in assisting the valuation of barley, and in the control of malting operations, for which it is accurate enough to be of considerable value in practice.

- XV. E. M. CROWTHER. "*Note on the Phosphoric Acid of Barley Grain.*" *Journal of the Institute of Brewing*, 1930. Vol. XXXVI, pp. 349-351.

Determinations of phosphoric acid in barley grain from experimental plots conducted in connection with the Institute of Brewing Research Scheme, showed that the total range of values was rather narrow (0.74 to 1.18 per cent  $P_2O_5$  in dry matter) and not closely connected with other analytical data from the samples. There was evidence that it was slightly increased by phosphatic and slightly decreased by nitrogenous manuring.

- XVI. A. W. GREENHILL. "*The Availability of Phosphatic Fertilisers as shown by an Examination of the Soil Solution and Plant Growth.*" *Journal of Agricultural Science*, 1930. Vol. XX, pp. 559-572.

The rate of growth of barley and changes in the phosphate concentration of the soil solution were followed in pots containing an acid soil limed at two rates and comparing slag, superphosphate, and no phosphate treatment. Liming increased the phosphate concentration. The effects of phosphatic fertilisers were somewhat variable; on lightly limed soil they reduced the phosphate con-



centration. There was no correlation between crop growth and phosphate concentration. It is suggested that barley can take up phosphoric acid directly from the solid particles of soil or fertiliser.

- XVII. J. CALDWELL. "A Note on the Dichotomous Branching of the Main Stem of the Tomato (*Lycopersicum esculentum*)."  
Annals of Botany, 1930. Vol. XLIV, pp. 495-498.

Occasionally in the experimental material it was noticed that plants appeared having dichotomously branched stems. One of these is described in this note. It is shown that the arrangement of the leaves indicates that the bifurcation is of the main stem and not axillary in origin. The stelar tissue divides exactly into two—one half going to each of the limits of the fork.

## STATISTICAL METHODS AND RESULTS

(Statistical Departments)

(a) General

- XVIII. F. E. ALLAN. "The General Form of the Orthogonal Polynomials for Simple Series, with Proofs of their Simple Properties." Proceedings of the Royal Society of Edinburgh, 1930. Vol. L, pp. 310-320.

In "Statistical Methods for Research Workers." R. A. Fisher has given a numerical method of polynomial fitting by means of orthogonal functions, developed from their terminal differences. It is shown here that the use of terminal differences may be made to supply direct and simple proofs of the algebraic properties of these polynomials, and a general formula for them.

- XIX. F. E. ALLAN. "A Percentile Table of the Relation between the True and the Observed Correlation Coefficient from a Sample of Four." Proceedings of the Cambridge Philosophical Society, 1930. Vol. XXVI, pp. 536-537.

In this paper a table is furnished, for samples of four, of the 95 per cent values of the transformed correlation,  $z$ , for different values of the correlation  $\zeta$  in the population sampled. The table is based on the distribution of the correlation coefficient given by R. A. Fisher in 1915.

- XX. R. A. FISHER. "Moments and Product Moments of Sampling Distributions." Proceedings of the London Mathematical Society, 1929. Vol. XXX, Series 2, pp. 199-238.

Much previous work has been expended in studying the distributions of various symmetric functions of the sample values of a variate having a known distribution, and it has been recognised that the moment functions of such statistics must be expressible in terms of the moment functions of the distribution sampled.

Only a few such expressions had, however, been obtained with exactitude, and the great complexity of these gave little promise of a solution of the general problem. It is here shown that, when the Pearsonian moments are replaced by more suitable statistics,