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## Rothamsted Report for 1951

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### Statistics Department

#### F. Yates

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## STATISTICS DEPARTMENT

By F. YATES

As in previous years the work of the department falls into two main sections—(1) design and analysis of experiments ; (2) sample surveys and operational research.

### DESIGN AND ANALYSIS OF EXPERIMENTS

The department has continued to design and analyse field and laboratory experiments for Rothamsted and other research stations. A great deal of work on these lines is also carried out for the National Agricultural Advisory Service. Dr. Boyd and Dr. Cooke of the Chemistry Department have held two courses of lectures for the National Agricultural Advisory Service on field experimentation, and a member of the department usually attends meetings of the Provincial Experiments Committees. A note by Dr. Boyd and Mr. Dyke on "The Place of Statistics in Field Experiments" has been circulated within the National Agricultural Advisory Service (51). Dr. Yates is a member of the Crop Experiments and Animal Experiments Sub-Committees of the Agricultural Improvement Council's Experimental Husbandry Committee and of a number of their working parties. On the animal side he has been assisted by Mr. Rees, who, with Mr. Westmacott, forms a small unit which has been specifically set up to deal with problems in the design and analysis of animal experiments.

The amount of computing work carried out in the department is now very considerable. A comparison with 1934 is made in the following table :—

	<i>No. of experiments</i>			<i>Plot yields analysed</i>		
	Rothamsted, Woburn and outside centres	N.A.A.S.	Total	Rothamsted, Woburn and outside centres	N.A.A.S.	Total
1934	115	—	115	9,142	—	9,142
1951	288	149	437	32,496	25,452	57,948

During this period the output of a computer has risen from about 2,500 plots to about 7,500 plots per annum. Part of this increase is due to some simplification of the processes of analysis, but it can largely be attributed to the improved types of calculating machines now in use, and to the careful organization of the work by the computers themselves. In considering these figures, it should be noted that almost all analyses are now carried out in duplicate by different computers and subsequently compared to detect arithmetical errors.

On the theoretical side, Mr. Healy has summarized the useful designs for 2<sup>n</sup> factorial experiments using 32 plots (39). Mr. Patterson has continued his investigation of experiments involving sequences of treatments and has published a further paper on this subject (41). These designs may be used for agricultural rotation experiments and for experiments on animals. He has also worked out the principles of analysis for the Rothamsted 3- and 4-course rotation experiments. The analysis of the 18 years' data from the

3-course experiment has been completed, and various modifications have now been introduced into the design of the experiment which it is hoped will throw light on the causes of the differences already produced by the treatments. A discussion of the experiment is given elsewhere in this Report (p. 135).

Dr. Yates has made some progress on his projected book on experimental design. The possible designs of the  $2^p \times 4^q$  type have been explored, using confounding and fractional replication where necessary. A scheme for including a fourth factor at three levels in a series of  $3^3$  experiments in 27 plots has been developed. A design for plant selection work in coffee in which 100 or so progenies, each of about 20 plants, are to be tested was worked out and a paper on this was read and discussed at a meeting of the Biometric Society (43). A discussion of the analyses of a poorly-designed long term rotation experiment is to be published in the Brazilian journal *Bragantia* (42).

#### SAMPLE SURVEYS AND OPERATIONAL RESEARCH

The Survey of Fertilizer Practice was continued during the year in 11 counties. The statistical analysis has been under the supervision of Mr. Church. A general report on the 1950 results has been issued (53) together with a report on the results from Cardiganshire in 1945 and 1950 (60). Mr. Church is also investigating sampling errors and biases in this survey and some interesting results have already emerged. A general discussion of the survey by Dr. Yates and Dr. Boyd was given in a paper before the Edinburgh meeting of the British Association (46).

The main field work in the Survey of Maincrop Potatoes came to an end last year, but further field sampling was carried out in 1951 to investigate yield forecasting. A report on the results from the Northern province has been written (50), and the final analysis of the complete results is nearly ready. Some results relating to the yields estimated by field sampling and the official Ministry of Agriculture estimates are set out below. The official estimates have been well below the sample figures in all three years. Detailed examination shows that this is due mainly to under-estimation of high yields.

#### *Yields of potatoes (1½ in. ware) in tons per acre*

	1948	1949	1950
Official estimates (excluding first earlies— sampled counties only) ... ..	7.8	6.8	7.8
Sample estimates ... ..	9.5	8.5	9.9
Excess of samples ... ..	+1.7	+1.7	+2.1

The sample estimates were checked by comparison with the farmers' weighed yields where these were available. There was excellent agreement in 1948 and 1949, but some discrepancy in 1950. Part at least of this discrepancy is believed to be due to losses during storage, since some of the farmers' weighings were carried out in November or December, and 1950 was a bad blight year.

*Yields of potatoes (1½ in. ware) in tons per acre*

				1948	1949	1950
Farmers' weighed yields	...	...	...	9.8	7.8	9.1
Sample yields on same fields	...	...	...	9.9	7.6	10.0
Excess of sample estimates	...	...	...	+0.1	-0.2	+0.9

Samples were taken in August, 1949, 1950 and 1951 to investigate the possibility of a system of crop forecasting. While further work is necessary before any definite conclusions as to the value of the method can be reached, the results so far attained suggest that reasonably satisfactory forecasts may be possible. The results are included in a general discussion of crop forecasting given by Dr. Yates at the Indian meeting of the International Statistical Institute (45).

The survey of Restored Opencast Coal Sites mentioned in last year's Report was carried out during 1951. Field work is not yet completed, but analysis is going ahead on the data so far available, and a preliminary report will soon be issued. The department is also assisting the National Institute of Agricultural Engineering in an operational survey of farm tractors.

Smaller surveys included a survey of brassica crops grown for stock feeding in Wales (54) and a survey of rabbit damage to winter wheat carried out by the Advisory Entomologists. Mrs. Lord and Mr. Lessells analysed a survey of ragwort infestation in Anglesey and Pembroke (55). Two main factors effective in controlling this weed were found to be grazing by sheep and mowing for hay. Ploughing and reseedling may cause a temporary improvement, but ragwort infestation builds up again in two or three years if management favours its spread.

Dr. Boyd has written a paper with Professor Ellison of the Department of Agriculture, University College of Wales, based on the results of the Survey of Marginal Land carried out in 1949 and 1950 (37). It is estimated that there is about 2.4 million acres of marginal land under private occupation. Leaving aside the acreage regarded as not worth improving, the present output per acre of this land could be increased by about 70 per cent by a capital investment of about £40-45 per acre; rather less than half this sum would be needed for improvements to the land itself, and most of the remainder for the construction of additional buildings, roads and services. As a result of his work on this survey Dr. Boyd was asked to become a member of a working party of the Cabinet Natural Resources (Technical) Committee, dealing with the relations between agriculture and forestry.

At the request of the United Nations Statistical Office, Dr. Yates attended a meeting of the Working Party of Experts on Statistical Information of the Inland Transport Committee, Economic Commission for Europe. As a result of this meeting he prepared two notes on sampling road vehicles (61, 62).

*Colonial work*

Mr. Hodnett has continued to deal with a number of enquiries from Colonial research workers. These have included discussions of agricultural, economic and population surveys and requests for

advice on the design and analysis of a wide variety of experiments. He has continued his study of published data on the fertilizer responses of sugar cane. Mr. Church has supervised the analysis of a large uniformity trial carried out at the Oil Palm Research Station, Nigeria, and Mr. Hodnett is analysing a similar trial on groundnuts from Tanganyika. These two analyses, which are being carried out on Hollerith equipment, should enable the workers concerned to choose the best size and shape of plot for their experiments. As usual, many Colonial workers have visited the department during the year, three of them for prolonged periods.

Dr. Yates visited Jamaica during January, where he led a seminar on sampling methods organized by the Institute of Social and Economic Research of the University College of the West Indies. He also paid a brief visit to the Imperial College of Tropical Agriculture, Trinidad.

#### *Other Work*

Dr. Boyd has written two notes summarizing published data on the effect of seed rate on the yield of cereals (34) and on factors affecting the yield of winter beans (52). He has also discussed economic and statistical aspects of vegetable and animal foods in a paper read at a conference of the Nutrition Society (33). This paper deals with the relative physiological efficiencies of the different farm animals and considers how far these measures of efficiency need to be qualified by economic considerations. With Mr. Church and Mr. Dunn, Dr. Boyd has also collated published figures of agricultural production with a view to comparing alternative estimates of the net agricultural output of the country as a whole over the last five years.

Mr. Lessells has written a report for the Agricultural Research Council on the varieties of cereals grown in England and Wales during 1947, using data from the Survey of Fertilizer Practice (57). He has also summarized published data on the effect of seed size and spacing distance on the yield of potatoes and is preparing a paper on the subject with Dr. Boyd.

A paper was completed by Mr. Dyke and Mrs Simpson on the results of a large collaborative experiment on methods of analysis of pyrethrum (36). On rather similar lines, Dr. Boyd and Mrs. Simpson prepared a report on the sources of error affecting determination of the lime, phosphate and potash status of a field based on data collected by the Advisory Soil Chemists over a period of years (59). For a sub-committee of the Analysts' Conference of the National Agricultural Advisory Service, Mr. Lessells has reported the results of an investigation into the comparability of the analytical methods in use at provincial centres (58).

Dr. Grundy has continued his work on the log-normal distribution encountered in the sampling of insect populations and a paper has been published (38). He also assisted the Physics Department in the numerical solution of differential equations. Mr. Dyke and Mr. Patterson have written up their method of analysing factorial experiments when the results take the form of proportions (35). Mr. Healy has continued to advise on the analysis of the data furnished by the Birmingham Anthropometric Survey, and a paper

on the general problems encountered in the analysis is nearing completion. Dr. Yates and Mr. Healy contributed to a correspondence in *Nature* concerned with methods of handling multiple measurements on the teeth of human beings and the great apes in relation to similar measurements on the anthropoid fossils recently discovered in South Africa (47). Some interesting general problems of multivariate analysis are involved, and further work on this topic is in progress. Mr. Healy has also published a table of the correction for natural mortality used in assays of insecticides, fungicides, etc. (40).

A new edition of "Statistical Tables for Biological, Agricultural and Medical Research Workers" has been prepared and is awaiting publication. Work on a new edition of "Sampling Methods for Censuses and Surveys" is in progress.

#### *Hollerith equipment*

The installation has continued to be used in a wide variety of problems. Its usefulness has been increased by the acquisition in March of a reproducer-summary punch. This machine enables rapid copying from one card to another, and also enables the results of calculations done on the Tabulator to be punched direct on to cards.

A variety of non-standard techniques have been devised to meet problems of statistical computing. Many of these involve the use of the modifications to the tabulator mentioned in last year's report. Mr. Avis has standardized a method for analysing a series of  $3^3$  factorial experiments and Mr. Dyke and Mr. Healy have worked out a method for solving the large systems of simultaneous equations that arise in the critical study of survey data.

#### STAFF

As mentioned above, Dr. Yates visited Jamaica and Trinidad in January and February. In March he visited Sweden under British Council auspices and gave lectures on modern statistical techniques in Stockholm, Lund, Ultuna and Uppsala. Dr. Yates spent July and August at the Instituto Agronomico, Campinas, Brazil, where he co-operated with members of the Statistics Division in a general review of the experimental methods used at the Research Station. He also visited a number of the regional stations attached to the Institute. He gave a series of lectures at the Institute, and a lecture on sampling methods to the Instituto Brasileiro de Geografia e Estatistica in Rio de Janeiro (44).

Dr. Yates also attended the fifth meeting of the United Nations Sub-Commission on Statistical Sampling held in Calcutta in December. Before this he attended meetings of the International Statistical Institute and the Biometric Society in New Delhi and Calcutta. While in India Dr. Yates also visited the Silvicultural Research Station at Dehra Dun and the Central Rice Station at Cuttack.

Mr. Healy spent five months in France under a scholarship from the Institut Nationale de la Recherche Agronomique. Most of the period was spent at the Station Centrale de la Zoologie Agricole at Versailles, but Mr. Healy also visited other research stations including the Institut des Tabacs at Bergerac. Towards the end of his

stay he gave a short course of lectures on statistical techniques in biology (56). During August, Dr. Grundy and Mr. Church attended a course in genetics at the John Innes Horticultural Institution.

Mrs. R. Lord resigned from the department at the end of the year, and Mr. Jolly left in May 1951 to take up an appointment at East Malling as statistician to the National Agricultural Advisory Service Horticultural Experiment Stations, specializing in experiments on fruit. Two new appointments to the scientific staff were made during the year; Miss E. Spetch from University College, London, and Mr. M. H. Westmacott from Corpus Christi College, Oxford.

TEMPORARY WORKERS 1951

*Great Britain*

J. K. W. Slater	National Institute of Agricultural Engineering	November 1950-October 1951
R. W. Shepherd	Norfolk Agricultural Station, Sprowston	May 7th to 18th, 1951
Neil Gilbert	Clare College, Cambridge	June-August 1951
W. B. Taylor	University College, London	July-September 1950, and August-November 1951

*Colonial*

M. P. Mulholland	Department of Agriculture, Nigeria	October 1950-January 1951
W. D. Burrowes	Department of Agriculture, Jamaica, British West Indies	June-October 1951
K. Lerche	Sisal Research Station, Thika, Kenya	October-November 1951
I. Watson	Department of Agriculture, Malaya	December 1951-

*Foreign*

S. C. Chua	Department of Statistics, Singapore	June-September 1951
Ana Maria Flores	Dirección de Estadística, Mexico City, Mexico	June-September 1951
M. Ollagnier	Institut des Recherches Pour les Huiles et Oléagineux, Paris	June-July 1951