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## Report for 1952

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## Statistics Department

### F. Yates

F. Yates (1953) *Statistics Department ; Report For 1952*, pp 129 - 133 - **DOI:**  
<https://doi.org/10.23637/ERADOC-1-74>

## STATISTICS DEPARTMENT

F. YATES

### DESIGN AND ANALYSIS OF EXPERIMENTS

The department has continued the design and analysis of field and laboratory experiments for Rothamsted and other research stations, and for the National Agricultural Advisory Service. The analytical work has again involved a very considerable computing effort. Members of the staff attend meetings of the National Agricultural Advisory Service Provincial Experiments Committees, and the department is regularly represented on committees responsible for co-ordinating the National Agricultural Advisory Service's experimental work and that of the Experimental Husbandry Farms.

An interesting piece of work in the animal husbandry field was the organization of a co-operative experimental programme on the effects of feeding antibiotics to pigs. This was undertaken at the request of the Agricultural Research Council, and the planning, supervision, analysis and reporting represented a joint piece of work by J. Wardley-Smith, of the Agricultural Research Council Secretariat, R. C. Cambell of the Agricultural Research Council Unit of Animal Reproduction and M. H. Westmacott of this department. Experiments were carried out at six Research Stations, Agricultural Colleges, Experimental Husbandry Farms, etc. The undertaking marks a step forward in the organization of simultaneous co-operative trials on urgent practical problems in animal husbandry.

F. B. Leech, with the assistance of D. H. Rees, has analysed the results of a large-scale field experiment on the feeding of iodinated casein and thyroxine to cows (159). Earlier work had led to the belief that the feeding of these thyroid-stimulating substances might substantially increase milk yield, but the effect of their long-term use on the health of the cows was unknown. In the present experiment there seemed to be no adverse effects on the health of the treated animals, but the effect of the treatment on milk yield was very small, the increase during the period of the treatment being largely counterbalanced by a decrease in the length of lactation.

Although the principles of design and analysis of short-term agricultural field trials are by now well-known, other biological data often present new problems of analysis. H. D. Patterson has collaborated in the interpretation of the results of a set of experiments to determine whether a fragment of ovarian tissue in the rat can generate new oocytes after the rest of the ovary has been removed (148). Patterson has continued to work on the problems of long-term agricultural experiments, and has published a paper on experiments with a fixed rotation of crops (149). In this paper he has analysed eighteen years' results from the Rothamsted 3-course experiment on the effects of ploughing in straw. Healy (144) has described methods of analysis for lattice experiments in which the results for one variety or treatment are missing, a situation that occurs fairly commonly in plant-breeding work. M. H.

Westmacott and W. J. Lessells have begun a study of techniques in grassland experiments.

In an article in *Nature* (150), F. Yates has raised a problem of great practical importance, namely how to make a rational decision on the number of experiments to be carried out on some topic of economic importance. In agricultural research, two situations commonly arise; a new treatment (such as the feeding of antibiotics to pigs) is suggested, and it is necessary to find out whether its application will be economically advantageous to farmers, or it may be required to find the most economic level of a certain treatment (such as a fertilizer dressing) which will be applied anyway. The second problem is the more tractable, and is dealt with in the *Nature* article. Taking sugar beet as an example, it is shown that, in order to determine optimum fertilizer dressings to be applied in all beet-growing areas, a yearly programme of sixty experiments, possibly falling to forty experiments after a few years, is economically justified. A programme averaging twenty-two experiments a year was in fact carried out between 1933 and 1949, and as many farmers do not follow the recommendations emerging from the experiments at all closely, this programme was probably at about the correct level. However, a more realistic aim was that of investigating differential responses in relation to soil analyses and soil type, and it was in fact shown that, for example, the use of nitrogen for sugar beet on fen soils was not an economic proposition. If the farmers who at present apply nitrogen on these soils refrained from doing so they would save about £25,000 annually, about twenty times the annual cost of the experiments. Very large economic gains can be expected from experiments with this broader aim in view, and a much larger programme would certainly be economically justified. The importance of this investigation is underlined by the fact that the sugar beet experiments are unique in British agriculture. On no other crop is there any adequate series of experiments on representative sites for which soil analysis and soil type data are recorded. Similar considerations must apply in very many fields besides agriculture.

The other problem, that of deciding whether to apply some kind of all-or-nothing treatment, is a good deal more difficult, raising a number of interesting points of statistical theory. F. Yates, P. M. Grundy and D. H. Rees are at present working on this topic. The investigation requires some very heavy computing, but some results of considerable interest have already been obtained.

#### SURVEYS AND OPERATIONAL RESEARCH

The main surveys dealt with during the year were the Survey of Restored Opencast Coal Sites and the Survey of Fertilizer Practice. The former survey was undertaken at the request of the Ministry of Agriculture in the hope of being able to assess the relative merits of different methods of restoration. Whilst the survey did suggest that different methods of restoration substantially affected the subsequent productivity, the results of the survey as a whole were disappointing, and it proved impossible to obtain clear answers on many of the points that had been raised (156, 157).

The Survey of Fertilizer Practice was carried out in ten districts, and a report on eight of these has been issued (158). The survey showed, amongst other things, that the large apparent decline in fertilizer consumption between 1950 and 1952 was due in part to decline in stocks held by farmers and merchants. The estimated figures (1,000 tons) for nitrogen, phosphate and potash are as follows:

	N		P <sub>2</sub> O <sub>5</sub>		K <sub>2</sub> O	
	<i>Supplies</i>	<i>Consumption</i>	<i>Supplies</i>	<i>Consumption</i>	<i>Supplies</i>	<i>Consumption</i>
1949-50	213	208	461	435	234	219
1950-51	211	202	427	411	225	216
1951-52	182	202	275	335	182	206

B. M. Church has brought together the results of some recent surveys in two papers (141). These are largely based on eight districts surveyed in 1944-45 and again in 1950. Trends in fertilizer consumption are examined, and it is shown that there are possibilities of increased production by the more general use of fertilizers on cereals, fodder roots and grassland.

G. V. Dyke and P. R. D. Avis have continued to work on the results of the Survey of Maincrop Potatoes, 1948-50. A paper discussing the yield figures is completed, and two further papers are in preparation dealing with the forecasting of final yields and with growers' practices. J. K. R. Wood has carried out theoretical investigations on different methods of estimation for this survey as part of his work for a Ph.D. thesis. F. B. Leech and B. M. Church are co-operating in the planning and analysis of a survey of animal diseases carried out in Surrey and Berkshire during the past three years by F. W. Withers (161). Other surveys include a survey of farm tractor utilization carried out by J. K. W. Slater of the National Institute of Agricultural Engineering in consultation with members of this department (160), and a survey of rabbit damage to winter wheat, supervised by M. H. Westmacott and G. V. Dyke.

Work has continued on the summarization of existing knowledge on agricultural problems. With members of other departments, D. A. Boyd has written a paper (140) on the manuring of field beans, based on experiments carried out at Rothamsted or organized from there. They show that a moderate dressing of farmyard manure ploughed in is an excellent form of manuring for this crop; in the absence of F.Y.M. the main need is for potash, phosphate dressings being usually not economic. A PK fertilizer placed in bands near the seed was twice as effective as the same fertilizer broadcast, and quite small dressings were adequate if applied in this way. High seed rates (up to 3 cwt. per acre) and early sowing were both advantageous. A similar paper by D. A. Boyd and W. J. Lessells on the effect of seed rate on the yield of potatoes is also completed.

A second edition of Sampling Methods for Censuses and Surveys has been prepared by F. Yates and is expected to appear during 1953. The results of several recent theoretical studies have been included. An important problem is that of estimating variances when the domains of study cut across the strata of a stratified

sample; a paper on this subject is being prepared by H. D. Patterson and J. K. R. Wood.

It was decided during the year to abandon work on the Precision Wheat Records, obtained before the war with a view to elucidating the effects of weather factors on crop yields. The work already carried out on these records has shown that no further useful results are likely to be obtained.

#### COLONIAL WORK

The department continues to assist workers from all parts of the Commonwealth with statistical problems. Most of this work is handled by G. E. Hodnett, the Colonial Office statistician. Twelve colonial workers have stayed in the department for periods up to eight weeks, and nineteen others have paid brief visits.

Hodnett has also summarized the results of twenty years' experiments on sugar cane in Trinidad (146) deriving standard responses to N, P, K and organic manures and relating these to soil factors. He has now completed a similar analysis for British Guiana. He has also analysed a uniformity trial on groundnuts carried out by the Overseas Food Corporation in Tanganyika (147). This experiment gives some guidance on the best shape and size of plot for use with this crop, and enables comparisons to be made between various alternative experimental designs.

#### OTHER WORK

M. J. R. Healy has continued his work in the field of anthropometry and human biology. In a paper (144) read before the Research Section of the Royal Statistical Society he has discussed the conduct and analysis of large-scale anthropometric surveys. The processes of analysis involve well-known statistical techniques, but their application needs more care than is sometimes realized. In the collection of the data, an appreciable proportion of measurements are frequently wrongly recorded and methods are described for avoiding this situation, or of dealing with it when it arises. Data of this kind form a useful proving ground for trying out techniques of multivariate analysis; the development of such techniques has hitherto been guided more by mathematical elegance than by practical considerations. One stumbling-block is the very heavy computing involved—punched card machines are valuable in this field, but are by no means a satisfactory solution to the problem. A similar statistical problem has arisen in connection with the fossil anthropoids discovered during recent years in South Africa. Claims have been made that the teeth of these fossils resemble those of man more nearly than those of the existing great apes. A closer statistical examination of these claims is being made in collaboration with Professor S. Zuckerman. Measurements are available for fairly large series of human and apes' teeth, and an adequate treatment of the data should be possible. Preliminary results appear to show that little useful discrimination can be achieved by means of the usual metrical characters of the teeth.

Healy has also collaborated with M. A. Watson of the Plant Pathology Department in the analysis of field data on virus infections of sugar beet relative to aphid abundance (87). A simple

mathematical model was set up to describe the spread of infection by the aphids, and was found to give a remarkably good explanation of the figures. P. M. Grundy has continued to work on the mathematical aspects of the work of the Entomology Department on insect populations. He has published a paper (142) on the fitting of a normal distribution to grouped data when detailed observations from one tail of the distribution are not available. With F. B. Leech, he has modified a nomogram proposed earlier by M. J. R. Healy for the analysis of biological assay with a quantitative response (144). The investigation shows that in one important type of assay the nomographic method is almost 100 per cent efficient; a recent theoretical advance by Finney is shown to have important practical implications.

The fourth edition of *Statistical Tables for Biological, Agricultural and Medical Research* was sent to the press during the year. Some new tables are included, and a few errors have been corrected. A good deal of the onerous work involved was undertaken by P. M. Grundy. D. H. Rees has surveyed the recent sampling literature in order to bring up-to-date the bibliography of *Sampling Methods for Censuses and Surveys*. A start has been made by P. R. D. Avis on the construction of a subject index of recent statistical literature. A scheme for organizing the mechanics of a card-index has been devised and systems of classification for various branches of the subject are being investigated.

#### STAFF

F. Yates visited the United States during June and July. He took part in the conference organized by the North Carolina Institute of Statistics at Blue Ridge, N.C., giving papers on sampling theory and experimental design. M. J. R. Healy and H. D. Patterson attended the summer meeting of the Biometric Society held jointly with the Pharmacological Society in Edinburgh, the former taking part in a question-and-answer session on biological assays. Members of the department gave a two-week course in field experimentation for Provincial Officers of the National Agricultural Advisory Service during February, and took part in a similar course organized by the British Council during May.

M. H. Westmacott has been selected as a member of the 1953 British Mount Everest Expedition.

A. T. Dunn left the department during the year, and G. V. Dyke transferred to the Field Experiments Section. New appointments were N. E. G. Gilbert (from Clare College, Cambridge) and F. B. Leech (from the Veterinary Laboratory, Weybridge). M. E. Davies and J. K. R. Wood were both appointed to the staff on the completion of two years' Ministry of Agriculture post-graduate scholarships, the latter on a temporary basis pending call-up. An exceptionally large number of temporary workers were accommodated during the year—two from Great Britain, twelve from the Commonwealth and five from other overseas countries.